Weatherwise

Vol. 13
No. 3

June
1960

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Dust Devil on Front Cover

Editor:

I am forwarding to you a most interesting dust devil that occurred in Miami on the afternoon of 13 March 1960. It occurred during an exhibition game between the Baltimore Orioles and Pittsburgh Pirates and stopped play for several minutes. The picture was taken by United Press International.

Unfortunately, detailed information regarding maximum height, direction, and other items of interest are not available.

The most significant aspect of the photograph is the center core that appears the length of this dust column. This core is accented and revealed by the dark background of the grandstands.

The following information was obtained from the Miami International Airport at about the time of the dust devil at Miami. Skies were partly cloudy from 1400 to 1600; wind east about 10 mph; temperature 70°, dew point 51°, and barometer 30.13"/1020.3 mb. The airport is located about three miles west of the stadium.

I thought perhaps you and the readers of *Weatherwise* might like to see a rather unique picture of a Florida dust devil.

ROY LEEP
Chief Meteorologist
WTVT Weather Service
Tampa–St. Petersburg, Fla.

Ed. Note: We always welcome weather-in-action photographs and would appreciate hearing from other readers when interesting weather comes their way.

Vol. 13, No. 3 June 1960

CONTENTS

The Hurricane Beacon
— Harry F. Hawkins 91

Weather Routing of Ships by the U. S. Navy
— Buckmaster, Albers, Ballenzweig, and Miller 94

The National Severe Local Storms Research Project
— Dansy T. Williams 99

The Weather at Gettysburg
— David M. Ludlum 101

Mississippi Delta Agricultural Weather Project
— Riley, Kish, and Measells 106

The Ice-Fall Problem
— James E. McDonald 110

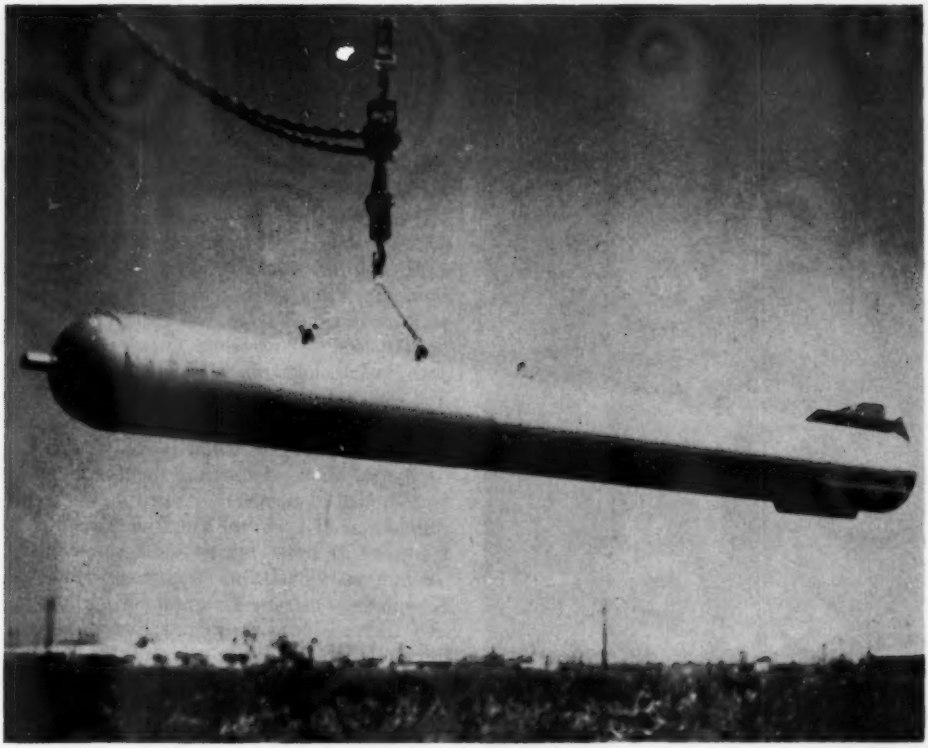
Atmospheric Phenomena at a Sunrise Total Solar Eclipse
— John W. Stewart 115

The Weather Past 118

Weatherwatch 120

Front Cover: Dust Devil at Miami Ball Park. See above. United Press International photo.

WEATHERWISE is published bimonthly for the American Meteorological Society. Office of publication, 45 Beacon St., Boston 8, Mass. Subscription is $4.00 per year; add 50 cents for postage to Canada and all countries in the Pan-American Postal Union; add $1.00 for all other foreign countries. Subscription orders, claims for missing numbers, changes of address, and advertising correspondence should be addressed to the society at 45 Beacon St., Boston 8, Mass. Editorial offices: Box 216, Princeton, N. J.



The hurricane beacon in packaged form before dropping. It measures about 10 feet long and almost one foot in diameter and weighs about 375 pounds. The redesigned package will be 7 feet long and 20 inches in diameter, and will weigh about 500 pounds.

The Hurricane Beacon

HARRY F. HAWKINS,
National Hurricane Research Project, U. S. Weather Bureau

SOMETIME during the coming hurricane season an especially equipped aircraft is going to seek out the eye of a full-blown hurricane at sea and drop a bomb-like balloon launcher right into the center. From the launcher will blossom a chute to slow the rate of descent. A Mylar balloon will unfurl and be rapidly filled with gas. The superpressure balloon, developed by the Air Force's Geophysics Research Directorate, will then carry a payload of batteries, transmitters, and gadgetry up to a preselected floating altitude—around 15,000 feet.

Tests of this system were run last season. All hardware functioned as expected, and the early studies of air motion in the hurricane's eye were amply justified. Signals from the Beacon were received from the VHF radio transmitter when it was a full 200 miles away and up to 23 hours after launching. More important than its mere survival was the fact that it was still in the eye of the

After release, a parachute slows descent. Here the balloon is shown in the process of inflation from gas contained under pressure in a bottle. The payload capsule is at the base of the balloon. The suspended empty canister is barely discernible below the parachute.

storm. Succeeding performances were also very encouraging.

Such accomplishments may not be too surprising to the initiated. The eye of a hurricane is well known to be a relatively cloud-free area with gentle cyclonic winds—all this located right in the heart of the hurricane. In the wall cloud of the hurricane, immediately surrounding the eye, whirl the strongest winds of the storm, perhaps 100, 125, 150 mph. Within the wall, torrential rains pour from towering wind-swept cumulonimbus build-ups, which may rise from 30,000 to 50,000 feet. Turbulence, vertical updrafts and violent chaos are not uncharacteristic of well developed wall clouds.

The eye is the relatively calm, serene area in the middle of this cloud arena. Usually it is circular, or nearly so, and may be some 12 to 35 miles in diameter. Since it marks the very center of a storm, which may be 300 to 500 or more miles across, its location is important. And, it is for this reason that the Beacon may become so useful. Its miniaturized transmitter emits regularly timed radio signals. These indicate not only the altitude of the balloon but also can be "homed upon" by a radio direction finder. As long as the Beacon remains in the eye, a reconnaissance plane can stand off at a distance in safe flying weather and "dial" the exact location of the storm center.

How does a balloon remain in the eye of the moving storm? Why is it not overtaken by the advancing rear wall and destroyed in the turbulence associated with the wall. This, of course, is always a possibility. But, studies have shown that near 15,000 ft. there is usually a slow indraft in the cyclonic winds of the eye itself. Moreover, the winds in the eye, although relatively gentle, increase markedly near the wall. Consequently, if the balloon drifts toward the wall, the wind speeds increase and the balloon is swept onward in a counterclockwise direction. If the level is indeed one of gentle indraft, the balloon is also carried inward toward the center of the eye: i.e., its trajectory relative to the moving storm becomes a slow inward spiral.

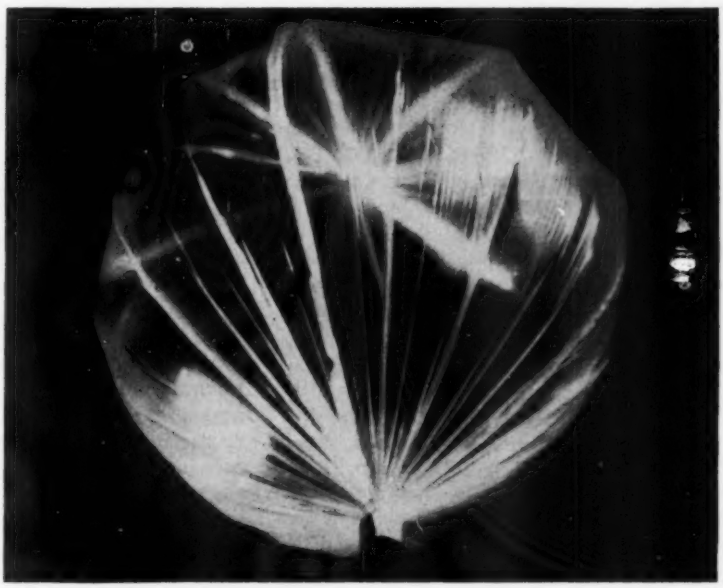
Encouraged by last year's successes, the physical payload is being redesigned for the coming trials. Two transmitters will be employed, the new (lower) frequency will permit radio direction finding from shore-based

stations up to 1000 miles away. The older frequencies will also be used to allow direction finding from the hurricane reconaissance planes. Also, the ballast load will be increased—ballast is automatically dumped when increased altitude is demanded by the control mechanism. A flashing red light will be mounted atop the balloon as an aid and warning to navigation. If the batteries become too weak to generate a useful radio signal, a self-destructive device will cause the balloon to collapse, and the entire package will drop into the sea. Ballast and batteries should last from 2 to 5 days.

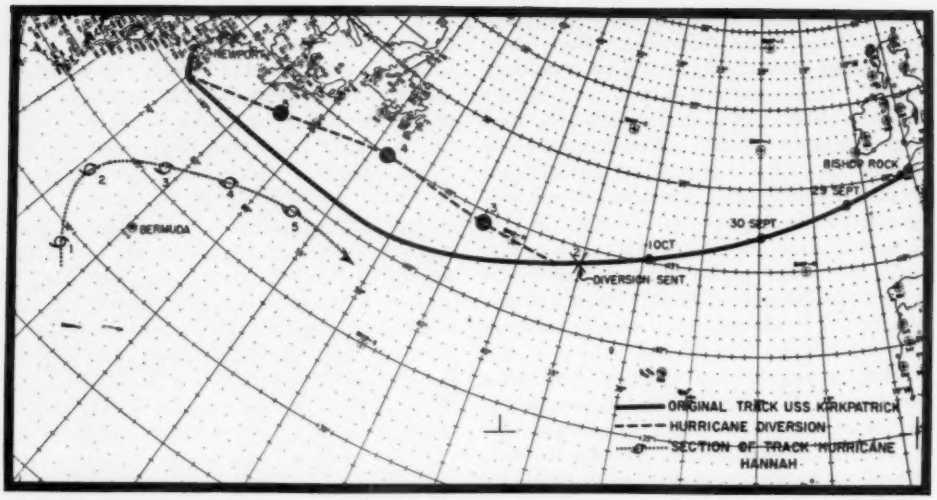
There is no guarantee that the correct level for floating this device can be chosen for storms of all intensities. Nevertheless, the possibilities of continuously tracking the hurricane's motion from remote shore-based locations deserve further exploration. There are other potentials which may be tried next year. Since the extremely low pressures in the hurricane are associated with anomalous warmth at middle and upper levels, it is planned to add a temperature sensing element to the payload. A current investigation seeks to relate numerically the temperatures at selected levels to storm depth or intensity. Thus, perhaps both the intensity and the location of the hurricane can be "dialed" continuously from shoreline safety. In addition, the balloon will be made radar reflective, and detailed studies of its motion in the eye could be made from radar time-lapse pictures. By this means, very detailed data on circulation in the eye would be readily available.

This entire development has been a joint project of the Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Massachusetts, and the National Hurricane Research Project of the U. S. Weather Bureau. The planes carrying this device were the well-known WB-50's of the 59th Weather Reconnaissance Squadron, Air Weather Service, United States Air Force.

Under contract, the electronic equipment was developed at Tufts University, and the "launcher" was engineered by Anderson, Greenwood and Company. This joint effort is an excellent example of cooperative research and development undertaken by agencies with mutual interests where various and extensive capabilities, resources, and facilities must be shared if the project is to be carried through to a successful conclusion.



After inflation, the parachute and empty canister detach and drop into the sea. The balloon shown is 12 feet in diameter. The payload is 9 inches in diameter and 10 inches long, and weighs about 20 pounds. The dual radio transmitters with batteries will necessitate a 35-pound payload.



Weather Routing of Ships by the U. S. Navy

LCDR. A. T. BUCKMASTER, USN; LCDR. H. W. ALBERS, USN; E. M. BALLENZWEIG AND J. F. MILLER, *Fleet Weather Facility, Norfolk, Virginia*

MARINERS have pitted themselves and their ships against the elements down through the ages and, until the last century, without any formal assistance from the meteorological and oceanographic sciences, except in a most general way. Recent experiments such as Dr. Thor Heyerdahl's KON-TIKI expedition give credence to theories demanding considerable oceanographic knowledge by some ancient civilizations. But it was not until the 19th century that any competent study of the world's oceanic climatology appeared.

Lieutenant Matthew F. Maury of the U. S. Navy earned the title of "The Pathfinder of the Seas" as a result of his work in the fields of meteorology and oceanography. His *Physical Geography of the Seas* (1855) was a monumental effort that produced usable charts of seasonal winds, currents, and weather factors; by using Maury's information, ship captains were able to cut from several days to several weeks off passages between distant ports. This was the first scientific attempt to weather route ships.

With the advent of steel hulls and steam, it was thought that the new, stronger self-propelled ships would be able to travel at will over the shortest routes across the oceans. History has proved that this is not the case, for the mightest of today's ships must give way to icebergs. Furthermore, severe storms delay and damage ships which cannot summon enough strength and power to stand up to nature's awesome forces.

It is not implied that the skilled mariner stands helpless before the elements, for his weather lore has been gathered over the milleniums and passed on down through the ages. Years spent at sea give the shrewd ship master an uncanny ability to predict the presence of stormy weather which lies out of sight over the horizon. And yet, the annual weather-caused losses in human lives, ships, and cargo are enough to stagger the imagination. It is apparent that a master's short-

range forecasting ability and strong ships do not guarantee safe and efficient shipping operation.

There are three approaches to weather routing ships—climatology, short-range forecasting, and extended forecasting. Each of these deserves examination.

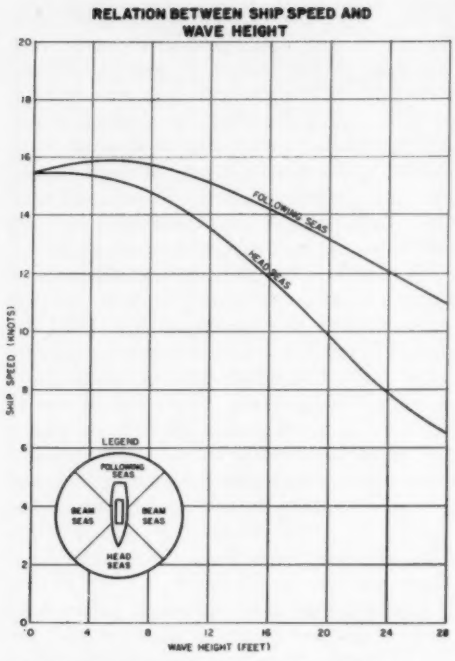
Issued each month by the U. S. Navy Hydrographic Office is a comprehensive climatological study of the Atlantic and Pacific Oceans. The presentations, in map form, are called *The Pilot Charts*. Contained thereon is such information as monthly averages of wind, current, gale frequency, sea level pressure, ice boundaries, temperature distribution, and selected storm tracks. All of these factors are important in determining the best route over which to steam a ship. Other important sources of climatological data are marine atlases and sailing directions. The principal disadvantage to the climatological approach to weather routing is the likelihood of encountering conditions which are large deviations from the average. Storm tracks vary during short periods. Unusually severe storms occur, and perhaps the most variable of all are sea states. Climatology is a valuable tool in the weather routing of ships, but its application is inefficient and limited.

The second approach to track selection is an improvement over the first, for the master of today's ship has more to aid him than climatology and a good weather-eye. With radio communications, the mariner is able to receive in timely fashion regularly scheduled oceanic weather broadcasts which include synoptic reports, "canned" maps, wind and sea forecasts, and ice warnings. Most fortunate of all is the captain with a radio facsimile receiver at his command. By merely tuning this device to the proper radio station, he may receive synoptic and prognostic surface, upper-air and high seas maps, all useful for plotting his course around and through the weather. But as weatherwise as they are, few ship captains claim to be meteorologists. Their ability to look several days into the future and predict with accuracy the features of the circulation is limited even with the aid of extended-period prognostic maps available by radio facsimile. Thus, a captain using the best information at hand may safely avoid one storm, and, by so doing, place his ship directly in the path of a larger, more severe disturbance. It may be concluded that the use of short-range forecasts can be very beneficial to the captain in finding his way through the weather, but that sole reliance on this information can be inefficient and costly. Radio transmission of weather information is not new, and yet the high cost of maritime insurance attests to the fact that this "do-it-yourself" approach does not enable a master to avoid all bad weather.

As has been indicated, neither climatology nor short-range forecasting methods will produce effective ship routings. The third approach to weather routing of ships is primarily based upon forecast periods of several days to more than a week. A method is needed for combining long-range predictions with a technique for selecting the best route through the forecast conditions. Although there are several techniques for ship routing, the method developed by Dr. Richard W. James of the Hydrographic Office is in use by the U. S. Navy and will be described.

James demonstrates that wave height influences ship speed to a greater extent than any other weather factor, so the primary tool of this method is a series of sea condition prognoses. Using ships of the Military Sea Transportation Service (MSTS), the James method, known as Optimum Track Ship Routing, was tested with the Hydrographic Office functioning as the routing activity. Results were encouraging, and after further test, evaluation and refinement, route recommendations were provided routinely for all oceanic sailings of MSTS. News of this service found its way to the U. S. Fleet. As a result of requests from combatants, it was decided to make Optimum Track Ship Routing (OTSR) available to all ships of the U. S. Navy.

It became apparent for a number of reasons that the work begun at the Hydrographic Office would have to be provided by a source more readily available to the Atlantic and Pacific Fleets. Since a large quantity of meteorological information is required for the application of OTSR, the already established Fleet Weather Facilities at Norfolk, Virginia, and Alameda, California, were selected. These particular facilities, headed by Commander A. L. Dodson and Commander J. P. Fleet, respectively, are accessible to the fleets they serve. The Ship Routing Departments are staffed with two naval officers and two



Relation between ship speed and wave height for following and head seas. This diagram illustrates the curvilinear relationship between these two factors. A curve showing the effects of beam conditions would lie between these two curves.

civilians, all of whom are meteorologists or oceanographers especially trained by the Hydrographic Office for their new positions. On 1 July 1959, following a one-year transition period, operational routing functions were transferred to Norfolk and Alameda, while the Hydrographic Office continued a limited routing program for research purposes. These three routing offices are currently issuing a total of about 110 track recommendations each month.

OTSR as originally envisioned would provide recommendations for the most rapid voyage between ports, with due consideration given to safety and passenger comfort. The practical officers of the navy, however, concentrated on the word "optimum" and began requesting recommendations which would optimize conditions for a particular mission, often beyond the intended scope of OTSR. One skipper, for example, requested *rough* sea conditions for the purpose of testing certain new combat eqipment. Another asked for a sunshine route, for his mission necessitated considerable work being done on deck, and rain or salt spray would have prevented its accomplishment. Troop transports are particularly interested in passenger comfort, as soldiers and marines suffering from *mal de mer* are in no condition to enter into combat or practice amphibious operations.

The initial ingredient in the process is a route request which contains the ship name, departure point and time, intended speed, and destination. The master may also include such pertinent information as unusual trim conditions or deck cargo loading. This information is vital and can have an important bearing upon the route selected. For example, a fast passenger liner is often able to outrun a storm which would overtake a slow freighter. Fully loaded, a ship is more seaworthy than when empty. A cruiser can advance through seas which would cause a small minesweeper to "heave to."

The route to be determined is based upon a combination of climatology, short-range, and long-range or extended forecasting, the latter being the primary consideration. Emphasis is placed upon the mean circulation expected during the duration of the voyage, a period varying from 4 or 5 days to 2 weeks. Initial portions of the voyage are selected on the basis of 3- to 5-day wave forecasts, the remainder being determined from a complex variety of considerations. Restrictions to visibility from fog, haze, or precipitation are also considered as these will cause a reduction in speed for safety.

The basic route selection results from a technique crudely analogous to pressure pattern air navigation. Both systems are concerned with the least time passage from origin to destination. Head winds and waves impede the progress of a ship in a manner similar to the way head winds slow an airplane. While the comparison between tail winds and following winds and seas is not as accurate, both may be thought of as more advantageous than when opposing. Empirical relationships have been developed which relate ship speed to wave height. Figure 1 is a schematic diagram which illustrates this relationship. As the waves increase above a certain height, the ship will reduce speed, either because of forces involved or the necessity for reduced engine speed required to prevent ship

damage. A ship encountering high head waves will lessen the shock by slowing down, a practice also followed by motorists on a rough country road.

Once the route is determined from a strictly meteorological point of view, it must be carefully checked for navigational inconsistency. Adjustments may have to be made to avoid proximity to coastal or shoal waters or ice hazards. When possible, heavy concentrations of shipping on opposite courses along shipping lanes are avoided.

Having satisfied himself that the proposed route is the best possible, the ship router sends the recommendation through naval communications channels to the ship master. From that time until the ship has arrived at her destination, a constant watch is kept on changing conditions which affect the ship's progress. Using a brief position and situation report submitted daily, the ship is located on an individual track chart and the data are compared with other synoptic ship reports. If a different track appears desirable or advisable at any time during the passage, the master is immediately notified. It must be understood that OTSR cannot guarantee smooth seas, light winds, and sunny skies, and there are times when no good route is available. It is under these situations that the ship router's skill is put to the test, for a slight difference in the ship's position can make a large difference in the wind and waves encountered.

A voyage of the destroyer escort *U.S.S. Kirkpatrick* from Copenhagen, Denmark, to Newport, Rhode Island, provides a good example of OTSR. The recommended route was sent on the 26th of September, 1959 (Figure 2). Uneventfully, the ship proceeded through the English Channel and into the North Atlantic. On October 2nd, it became apparent that Hurricane Hannah would pass dangerously close to the *Kirkpatrick*'s track on the 4th or 5th. Based upon careful analysis of the probable movements of this severe storm, a recommended diversion was sent to the commanding officer. He carefully considered this recommendation in light of fuel available, his assigned mission, and other operational considerations, and altered course. Hannah churned eastward, a safe distance to the south of the new track, and appended to the *Kirkpatrick*'s final position report was the comment, "Thank you for your excellent services."

Although the vast majority of the routed ships do not encounter hurricanes, the example does illustrate that OTSR can and does provide a valuable service to the maritime community.

As is the case with any service, customer

Commander A. L. Dodson, Officer in Charge, Fleet Weather Facility, Norfolk, Virginia (right) discusses sea conditions in the Atlantic with members of his staff, (left to right) Meteorologist J. F. Miller; Commander H. F. Silsby, Jr., Assistant Officer in Charge; Oceanographer E. M. Ballenzweig, and Lieutenant Commander H. W. Albers.

satisfaction is required. It is results that count. But evaluation of the effectiveness of OTSR runs into such intangibles as damage which does not occur, cargoes which arrive in good condition, and passengers who do not become seasick. There is no effective way of measuring these factors against possibilities. However, operating costs can be weighed, as can time saved. In a letter to the ship routing facilities, the Commander, Military Sea Transportation Service, indicated fuel savings running into several hundred thousand dollars during 1958. Naval commands have evaluated the service from the standpoint of operational efficiency and have concluded that OTSR is definitely beneficial. These comments are indicative of acceptance of OTSR, but the most rewarding gauge of effectiveness comes from the captains who repeatedly request the service.

Honesty and objectivity require mention of the users who have been dissatisfied with the service. Some passages have been extremely rough. A few ships have reported damage to hull or cargo, and routed ships are occasionally delayed. Forecasting and prognostication are not infallible; until they become so, route recommendations based upon these imperfect products will, from time to time, be something less than desired.

Is there any chance for improvement of the methods and techniques? What are the ramifications of OTSR? Are there commercial applications of OTSR? These questions are frequently asked.

Research toward the improvement of the techniques is programmed. The Hydrographic Office has been delegated the responsibility for collecting ship performance data, and the Office of the Naval Weather Service is seeking other approaches to improving existing methods and investigating new and untried techniques, including the use of electronic computers for solution of some of the more sophisticated prognostic methods. The Naval Weather Research Facility is currently studying the application of electronic computers in the selection of the least time track. New ideas are tried, evaluated, and retained or discarded. Continuing effort along these lines will be pursued.

It can be demonstrated that OTSR efficiency is directly related to the ability to forecast weather development and progression. Many interests and activities are engaged in extensive research programs intended to improve these abilities, and it is expected that progress will be made. OTSR, dependent upon meteorology and oceanography, will keep step and increase in efficiency.

At the present time, commercial routing services are available from several companies in the United States. In the Netherlands about 20–25 commercial ships are routed by weather each month. At least one Asian and two European countries have made official inquiries about American methods. The weather routing of vessels is here to stay.

When sufficient statistics have been gathered, it is envisioned that the cost of marine insurance will decrease for ships which utilize a weather routing service able to demonstrate that less damage and cargo loss result from use of its recommendations. Once a reality, this one factor will cause rapid growth of the ship-routing industry, for the cost of maritime insurance is high.

Vice Admiral John D. Will, USN (Ret.), former Commander, MSTS, and now President of the American Export Lines, speaking of OTSR, stated, "A new horizon has been sighted through the far-sighted men who constantly strive to make ocean travel a more modern and safer mode of transportation. It is up to those of us in the maritime industry to see that this new aid to navigation is utilized to the fullest extent possible."

REFERENCES

Heyerdahl, Thor, 1950: *Kon Tiki.* Chicago, Rand McNally, 304 pp.

Maury, M. F., 1855: *Physical Geography of the Sea.* New York, Harper Bros., 274 pp.

U. S. Weather Bureau and U. S. Navy Hydrographic Office, 1959: *Climatological and Oceanographic Atlas for Mariners.* Washington, D. C., 182 charts and 7 pp.

U. S. Navy Hydrographic Office: *Sailing Directions.* 60 Volumes.

James, R. W., 1957: *Application of Wave Forecasts to Marine Navigation.* U. S. Navy Hydrographic Office. vii and 78 pp.

James, R. W., and G. L. Hanssen, 1958: *Evaluation of the U. S. Navy Hydrographic Office Ship Routing Program.* Washington, D. C. H.O. Tech. Report No. 53, 31 pp.

The National Severe Local Storms Research Project

DANSY T. WILLIAMS, *U. S. Weather Bureau, Kansas City, Missouri*

OPERATIONS of the National Severe Local Storms Research Project (NSLSRP) began on March 24th of this year, when the Weather Bureau's leased P-38 made its first flight of the season into a thunderstorm area. It is one of several aircraft being used this year in a concentrated assault on the problem of severe local storms.

Organization of the NSLSRP has evolved from a number of conferences in which the nation's experts have gathered. The project will operate for the three-year period, 1960 through 1962, and possibly longer. It is being conducted by the U. S. Weather Bureau in cooperation with several other agencies. These include the National Aeronautics and Space Agency (NASA); the Federal Aviation Authority (FAA); the U. S. Air Force's Wright Air Development Division (WADD), Geophysical Research Directorate (GRD), Air Defense Command (ADC), and Air Weather Service (AWS); and the U. S. Navy's Office of Naval Research (ONR) and Weather Research Facility at Norfolk, Virginia. C. F. Van Thullenar, U. S. Weather Bureau, is director of the project, and the operational office is at Will Rogers Field, Oklahoma City, Oklahoma.

Since the severe local storm is meteorologically rather small, relatively short in duration, and excessively proportioned in the vertical, conventional methods of observation are apt to miss most of it. Detailed observations at frequent intervals and numerous points are required, and the project is meeting this need through the use of aircraft, special surface networks, special rawinsonde observations, and rocket photography. Basic objectives include isolation of mechanisms that generate, maintain, and dissipate the severe local storm; identification of those parameters that determine its severity; and the application of this knowledge to minimize its hazards. Since most severe local storms are associated with squall lines, the primary target in 1960 is a study of squall lines.

Flight planning and dispatching of aircraft is accomplished from the operational base at Oklahoma City, Oklahoma, utilizing forecast information from the Severe Local Storms Center, Kansas City, Missouri. Individual aircraft are dispatched on the basis of their observational capabilities and the objectives that might be achieved for that day. Normally all of the aircraft do not fly the same mission.

The T-33 used by the National Aeronautics and Space Authority and the Wright Air Development Division, USAF, for thunderstorm and squall line turbulence measurements in coordination with the National Severe Storms Research Project. NASA photo.

Two DC-6's and a B-57 of the National Hurricane Research Project have been assigned to the NSLSRP for the months of March, April, and May. A T-33, F-102, and F-106 are being provided by WADD. Also on call are an A-3D from the Navy Weather Research Facility, and a C-130 from GRD.

The P-38 is used primarily for taking soundings. Temperature, humidity, and pressure are recorded as the aircraft makes spiral ascents or descents through a layer. A typical flight plan, shown in Figure 1, provides soundings on either side of a squall line.

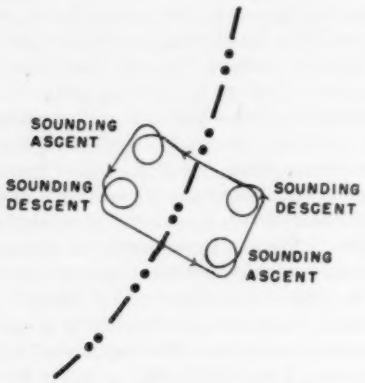


FIG. 1. A flight plan for the P-38. The soundings, shown as loops in the figure, are made from the surface to 500 mbs or higher. Useful data are also gathered on the traverses between soundings.

The DC-6s are used primarily in level flight. A simple plan, shown in Figure 2, consists of horizontal traverses along rectangles on either side of a front or squall line. Observations from this plan are used to detail small-scale horizontal gradients of temperature, moisture, and wind relative to the front or squall line.

The B-57 is used in level flight at high altitude. A typical flight plan, shown in Figure 3, employs a saw-toothed pattern designed to provide areal measurements of wind and temperature in the vicinity of the jet stream. Similar plans will be flown by the A-3D, and in some instances both aircraft will probe the same area. Instrumentation of the A-3D is designed to measure clear air turbulence that may be encountered in the vicinity of the jet stream.

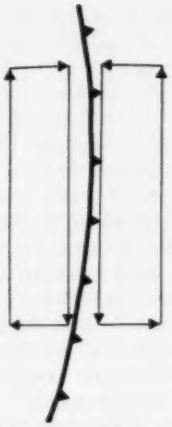


FIG. 2. A flight plan for the DC-6's. Each DC-6 flies one of the rectangles. Observations provide an areal representation of data on both sides of a front or squall line without requiring penetrations of the line.

The T-33, F-102, and F-106 are being used by WADD and NASA to study turbulence and flame-out associated with thunderstorms. Liquid water content of thunderstorm tops will also be measured. Flight plans for these aircraft require actual penetration of the storms at many levels. First penetrations were made west of Oklahoma City on the afternoon of 28 April 1960. Cells penetrated were part of a storm system which produced

FIG. 3. A flight plan for the B-57. The saw-tooth path is designed to provide wind and temperature measurements that can be used to describe the jet stream in the vicinity of severe local storms.

(*Continued on page 131*)

The High Tide of the Confederacy as conceived by a contemporary artist. Gen. Armistead, leading Pickett's Charge, was shot down as he reached a Union battery and the spearhead of the attacking force was blunted. Note that cloud types correspond to Prof. Jacobs' notation of scattered strato-cumulus. The Bettmann Archive.

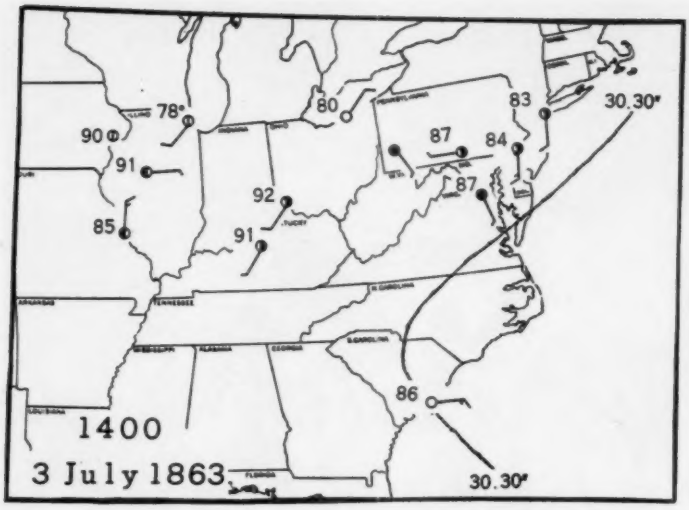
The Weather at Gettysburg

DAVID M. LUDLUM

"GREAT battles of Gettysburg fought" was the simple entry of Michael Jacobs in his meteorological register for 1–3 July 1863. For almost twenty-five years Prof. Jacobs, at his post as professor of mathematics and science at Pennsylvania College, had been noting the vagaries of the Gettysburg weather scene, first for the state system of The Franklin Institute of Philadelphia (1839—) and later for the national organization of the Smithsonian Institution in Washington (1849—).

It was one of those unpredictable turns of fate that brought almost 200,000 men, bent on killing each other, from the far reaches of the North and the South to the quiet valley of Gettysburg in southern Pennsylvania, a remote country retreat that Prof. Jacobs knew so intimately and loved so well. He had tramped every acre of its woods and fields in company with his students on nature walks, geological surveys, and for viewing the stars or an aurora. More than anyone else he knew what nature had placed there for man's use.

We do not know just what prompted this man of science and the gospel to remain at his erstwhile peaceful post on the college campus when the greatest battle drama in the nation's history was being played out all around. No doubt over a quarter-century of methodical instrument reading and scientific investigation had instilled a regularity of



A simplified weather map for 1400, 3 July 1863. Temperature, sky condition, and wind are represented. Stations are those which reported to the Smithsonian Institution with the exception of the Charleston Board of Health report. Only one tentative isobar could be drawn since inland pressures were not reduced to sea level and the exact height of most barometers could not be determined.

daily routine that not even the great cataclysm of war could disturb. Not only did he take his three weather observations at the stated times, but he also jotted down impressions of the action which enabled him to compose his *Notes on the Rebel Invasion of Maryland and Pennsylvania,* an early first-hand account of the battles which contained much local color not found in other works on the subject.

The College and the Battle

Though a large part of the student body of Pennsylvania College (now called Gettysburg College) had formed a company and marched off to join the Pennsylvania militia two weeks before, the few remaining students assembled as usual for chapel and recitations on Friday morning July 1st. The appearance of signal officers of the Union Army who made use of the cupola atop Old Dorm to reconnoitre the countryside caused some apprehension; then the breaking-out of rifle fire to the west of town in mid-morning soon put an end to class exercises. Prof. Jacobs tells us that it was from the cupola and with the assistance of "college officers," probably himself, that Cemetery Hill to the south of Gettysburg was selected by General Howard as the best terrain feature on which to establish a defense.

It was to Cemetery Hill and its flanks that the Union 11th Corps retreated late in the afternoon when forced back by the ever-increasing pressure of the full Confederate Army's advance. Thereafter the college grounds, along with Prof. Jacobs and his meteorological instruments, remained within the Southern lines until the withdrawal on the 4th. The College buildings, though an occasional stray bullet or shell fell nearby, were used as hospital quarters. Prof. Jacobs further relates in his *Notes* that General Robert E. Lee climbed the cupola on Sunday morning of the 3rd to determine the best point to direct the attack to be made that afternoon by General Pickett's freshly-arrived brigade. Prof. Jacobs was a Union sympathizer, and his allegation that Lee had used a hospital as an observation post has caused a partisan controversy that continues to the present day.

The Observations

The meteorological observations made by Prof. Jacobs, with the occasional assistance of his son Henry, have been transcribed from the microfilm of the official manuscript Smithsonian Institution records. The originals were destroyed about 1940 after the sheets had been microfilmed. The negative is now at the National Weather Records Center in

Asheville, North Carolina, and copies may be consulted at the National Archives in Washington, D. C.

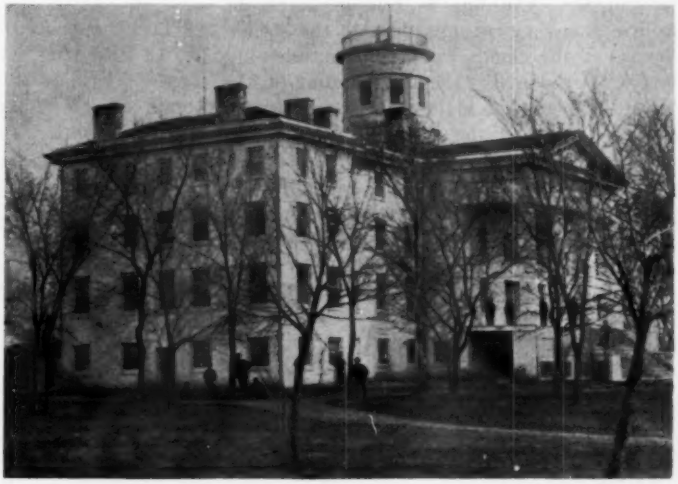
1 July	0700	1400	2100
Temp.	72°	76°	74°
Bar.	29.60″	29.60″	29.59″
Wind	S 1	S 1	S 1
Clouds:			
Cover	10/10	10/10	10/10
Direction	S	S	S
2 July			
Temp.	74°	81°	76°
Bar.	29.65″	29.67″	29.64″
Wind	S 1	S 2	S 1
Clouds:			
Cover	10/10	7/10	9/10
Direction	S	W	W
3 July			
Temp.	73°	87°	76°
Bar.	29.67″	29.67″	29.66″
Wind	SSW 1	SSW 1	SW 2
Clouds:			
Cover	10/10	4/10	7/10
Direction	S	W	SW
4 July			
Temp.	74°	76°	69°
Bar.	29.66″	29.69″	29.61″
Wind	SW 1	SW 1	SW 1
Clouds:			
Cover	10/10	10/10	10/10
Direction	WSW	WSW	WSW

Synoptic Situation

The general weather map on the opening days of July 1863 presented a picture of typical stagnant, summertime conditions. A Bermuda High situation prevailed, with an anticyclonic strengthening on the 1st and 2nd, to reach a pressure climax about 1400 on the 3rd, the very hour that the ill-fated Pickett's Charge was being readied in the Confederate lines. Though the Civil War largely disrupted the Smithsonian meteorological system, we do have reliable barometric observations at Charleston, South Carolina, and at Annapolis, Maryland; both may be considered approximate sea level pressures.

At Charleston the barometer rose from 30.19″ at 1400/1st to 30.30″ at 1400/3rd. Annapolis had the same general rise, the figures being from 30.17″ to 30.26″ during the same period. Thereafter, pressure fell at both places: gradually at Charleston and somewhat faster at Annapolis. By 1400/5th, 48 hours later, the readings had dropped 0.15″ at Annapolis and 0.11″ at Charleston —certainly not a very precipitate fall, but indicating a gradual offshore movement of the Bermuda High. Prof. Jacobs' barometer inland at Gettysburg rose and fell a lesser amount, from 29.60″ to 29.69″, and then slumped off to 29.55″. These figures are station pressures, not corrected for temperature or the 624-ft elevation.

A study of station records farther west in the Great Lakes area and in the Ohio Valley from the 1st to 5th indicates that no cold front was present, at least as far west as the Mississippi River. The barometer at Cincinnati followed the same pressure curve and



The Main Building of Pennsylvania College, known as Old Dorm, as it appeared about 1882 in much the same condition as during the Civil War. Prof. Jacobs' science room was on the second floor of the near wing. The cupola commanded an extensive view of the countryside. Photo by Tipton, courtesy of the Library of Gettysburg College.

timing as those along the Atlantic Coast. Furthermore, there were no significant wind direction shift nor sharp wind speed increase there that would indicate anything but a very flat pressure gradient.

All of the various weather elements observed by Prof. Jacobs at Gettysburg combined to indicate the transformation of a modified polar air mass into one with tropical characteristics during the battle period. The temperature, moderate for the season on the first two days, turned warm, but not hot, on the 3rd—the air became increasingly humid, but not excessively so—the sky remained overcast on the 1st, broken during the day of the 2nd, and scattered on the afternoon of the 3rd—wind movement on all three days was light to gentle, force 1 or 2.

For military operations, the battle field should have been solid and trackable for artillery and cavalry. Though June had been drier than normal, a heavy rain of 1.28″ had fallen on the 25–27th and a light fall of 0.15″ on the night of the 29–30th. No rain fell at Gettysburg during the period of actual fighting.

The mercury on the third and crucial day rose from 74° at 0700 to a reading of 87° at 1400, about the time that Pickett's Charge was being prepared. At the High Tide of the Confederacy (about 1530 according to our best authority), the mercury in the shade probably stood just below the 90°-mark. Indoors, the thermometer attached to his barometer read 76° at 1400, a rather comfortable figure. Out on the field of battle, of course, sun temperatures through the sizable breaks in the clouds would run considerably higher. Incidentally, the 1400 reading of 87° on the 3rd was the highest at Gettysburg for that hour during the entire month of July 1863.

The meteorological element which proved most unfavorable to the fighting men and would accentuate discomfort and induce fatigue centered around the lack of wind movement. With tropical air now present and humidities running high, the discomfort index stood high—perspiration would have been the rule of the afternoon, even without the presence of an enemy army a few yards away. If pictorial representations of the clothing worn by combatants are typical, certainly the heavy blouses and trousers, suitable for winter campaigning, also would have contributed to the discomfort of the foot soldier.

The Rains and Retreat

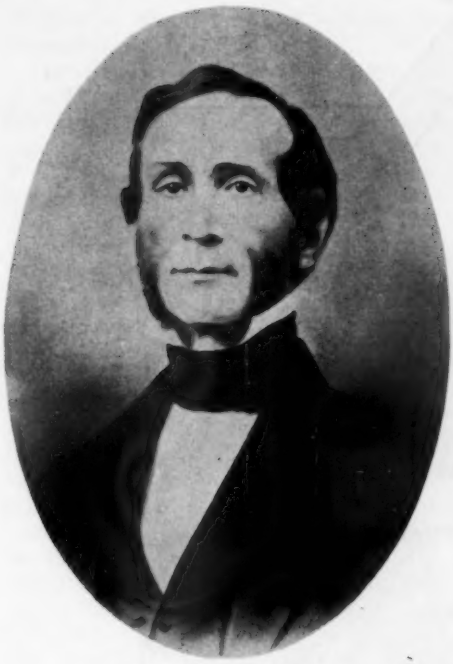
With the repulse of the futile attack, the fighting soon died down as the Cnofederates straggled back to their lines to await the expected Union counter blow. The weather elements, quiescent during the actual fighting, now assumed a more active role that was to complicate both Lee's problem of withdrawal and General Meade's oft-criticized attempts at pursuit. The stagnant anticyclonic situation gave way late on the 3rd to a showery period which continued intermittently until Lee reached Virginia on the 13th.

A light shower fell at Washington, D. C., on the afternoon of the 3rd, and at Harrisburg a "thundergust," commencing at 2030, continued intermittently until 1800 of the 4th—a sizable amount of moisture, 2.79″, was measured in the rain gage of John Heisely at the Pennsylvania capital, 35 miles to the northeast of Gettysburg. Prof. Jacobs' records show rain at 0600 on the 4th and again from 1415 to 1600—for a total day's catch of 1.39″. Washington, D. C., had 0.32″ on the 4th during "a fine shower." The rainfall record at Harrisburg for the days after the battle follows:

July	4	2.79″	9	.00
	5	1.32	10	.39
	6	.35	11	.00
	7	.00	12	3.47
	8	3.51	13	.20

Lee commenced his withdrawal from the battle field after dark of the 4th. "The night was very bad—thunder and lightning, torrents of rain," wrote British correspondent Col. Fremantle, "the road knee-deep in mud and water." Lee's main forces, making only a mile an hour, reached Hagerstown, Maryland, on the 6–7th and Williamsport, on the Potomac River, on the 8–9th.

The southerly and southwesterly circulation which had prevailed since July 1st gave way to a northeasterly flow on the night of the 6–7th and a second heavy rainfall soon followed. It appeared that a relatively shallow low pressure system moved northward along the coast as the Gettysburg barometer continued to fall until 0700/9th when it stood at 29.30″, almost 0.40″ lower than during the



MICHAEL JACOBS, D.D.
Professor, 1832–1871.
(Copied by W. H. Tipton, courtesy of the Library of Gettysburg College).

battle. The storm on the 8th brought 1.30″ at Gettysburg, with probably higher amounts in the mountains to the west.

The temporary pontoon bridge across the Potomac had been partially destroyed by Union raiders. Lee, with his back to a stream now in high flood, found himself in a precarious position. The rains of the 8th raised the river to a near-record height. Even the city of Washington was isolated on the east by a washout of a key railroad bridge. It is significant that no rain fell at Pittsburgh during this period, indicating that the drenching showers were confined to the area east of the mountains where maritime air from the Atlantic precipitated its moisture against the mountain barrier formed by the Alleghenies.

Lee quickly threw a strong defensive perimeter around his position between Williamsport and Falling Water along the Potomac; so strong was the position of the veteran Southern Army that at a council of war the Union generals were hesitant to urge an attack. No doubt the wretched condition of the roads slowed the Northern Army's ability to bring the necessary troops and equipment to the scene. Lee reconstructed the damaged pontoon bridge, but had to wait until the river dropped low enough to permit the bulk of the infantry to ford the stream on foot since the lone bridge did not have the capacity to permit an efficient, simultaneous withdrawal of so many troops. The Southerners commenced crossing on the evening of the 13th and completed the complicated manoeuver safely by 1300 of the 14th.

MICHAEL JACOBS

1808–1871

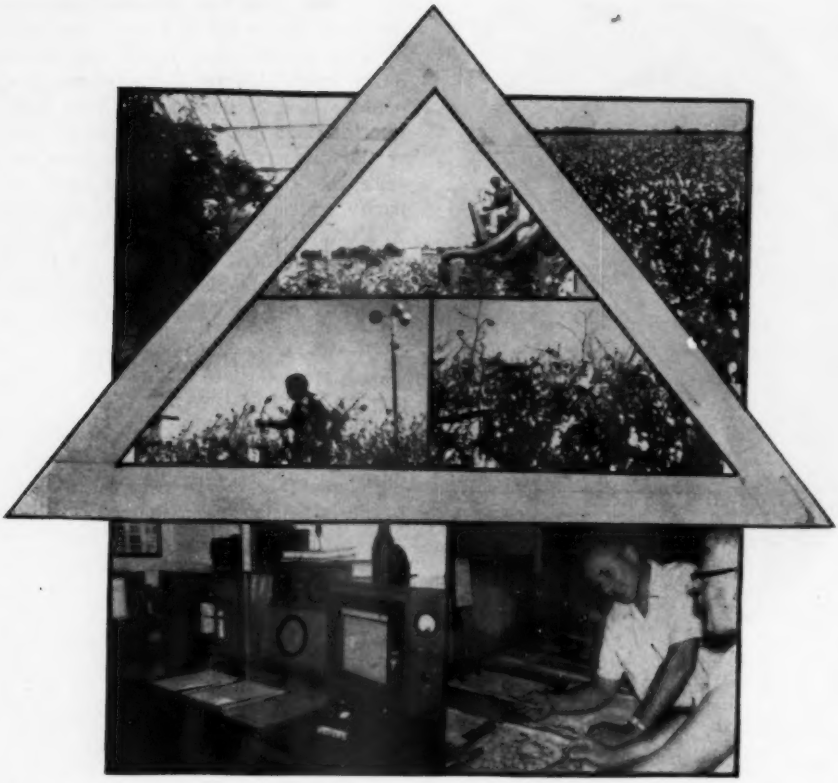
Michael Jacobs deserves an honored place in the annals of American meteorology. Throughout his 37-year career he was primarily a teacher. His course in meteorology instituted in 1841 is said to have been the second such course ever presented at an American college. After his death weather officials in the Signal Corps, U. S. Army, attempted to reassemble his material and notes so that a similar course could be presented to Government weathermen.

Prof. Jacobs was born in Franklin County, Pennsylvania, in 1808, of Alsatian stock. He was graduated with honors from Jefferson College in 1828 and soon joined his brother who had just founded the Gettysburg Classical School. When the college was organized in 1832, the young teacher of 24-years was elected to the professorship of mathematics and science, a post he held until failing health compelled him to resign in 1866, though he continued to serve as professor emeritus until his death in 1871. He also studied theology privately and was licensed by the West Pennsylvania Synod of the Lutheran Church in 1832.

The historian of Gettysburg College has summed up his meteorological work with succinct expression:

"Professor Jacobs loved nature. No field of natural science was foreign to his interests. He was an omnivorous reader. As far as time and strength permitted, he studied the great scientific works of the day. But for him Nature was always more important than books about nature. He observed the

(*Continued on page 130*)



The joint effort by the (1) Weather Bureau and the (2) Agricultural Research Service to make (4) agriculture more efficient. The triangle in the middle (3) shows the combined research by agricultural specialists and weather specialists in a cotton field of the Mississippi Agricultural Experiment Station, Delta Branch, Stoneville, Mississippi.

Mississippi Delta Agricultural Weather Project

A Weather Bureau Pilot Project

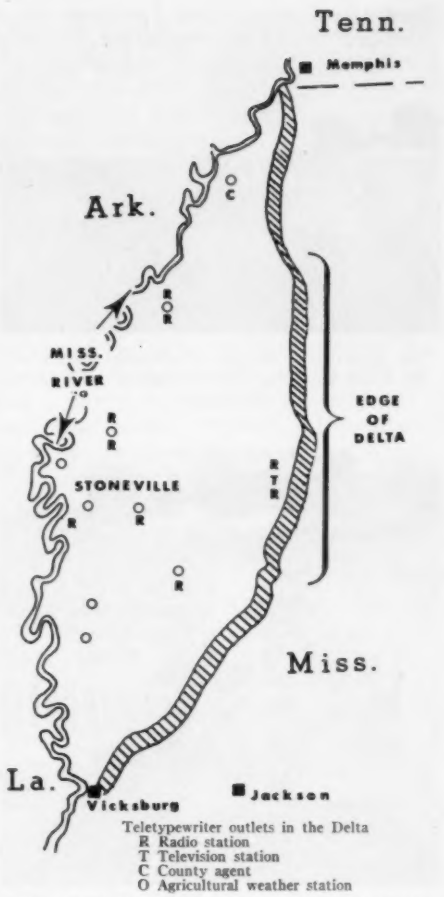
J. A. RILEY, *Research Agricultural Meteorologist, USWB, Stoneville, Miss.*, A. J. KISH AND J. W. MEASELLS, *Agricultural Meteorologists, USWB, Jackson, Miss.*

IN ancient times the Greek letter Delta symbolized the flood plain at the mouth of the Nile. Later it came to mean the alluvial plain at the mouth of any river. In June 1958 this ancient Greek letter took on a new symbolism, at least for the Weather Bureau. At that time, Congress appropriated funds and directed that the Weather Bureau establish a pilot project in the Mississippi Delta. The objective was to develop methods of providing a weather service to meet the specific needs of agriculture. Thus this ancient Delta triangle now signifies the combination of the Weather Bureau and agricultural research

in the joint effort of making farming more efficient.

The area designated as the Mississippi Delta is not at the mouth of the river; however, it is a rich alluvial plain and comprises about the northwest one-sixth of the State of Mississippi and is famous the world over for high-quality staple cotton. About two-thirds of the farm acreage is devoted to cotton growing and cotton is still "King" in the area. The Delta Branch Experiment Station, employing about 150 people, is one of the leading cotton research centers in the world; however, the studies are not limited to cotton alone but include cereals, small grains, livestock, horticulture, pasture management, and insect control. The Department of Agriculture maintains its largest ginning research laboratory there in cooperation with the Experiment Station. The Forest Service has its Southeastern Hardwoods Research Center at the Experiment Station. With all its facilities, the Delta Branch Experiment Station is one of the largest and most famous agricultural research centers in the country and is well suited for the inauguration of an agricultural weather project.

The project has a four-point program: specific forecasts for agriculture, specialized observations of use to agriculture, a rapid means of communicating weather information to the farmer, and a research program to relate weather information to agricultural needs. Four stations participate in the project: Jackson and Vicksburg, Mississippi; Memphis, Tennessee; and the newly established Agricultural Service Office at Stoneville, the site of the Delta Branch Experiment Station.



Map of the Mississippi Delta showing the location of observation stations and the news outlets of the project.

Specialized Forecasts

To meet the specialized needs of agriculture, it was felt that the forecast should be more specific and contain more elements than regular forecasts. A completely new format designed by Mr. G. V. Fish of the Jackson office was adopted for the project. These specialized agricultural forecasts are issued for the Delta by the Jackson office three times a day and include three 12-hour periods with a further outlook for the third day.

Sky condition is forecast in tenths of cloudiness, instead of the usual clear, partly cloudy, or cloudy. The rainfall forecast states the per cent of the Delta that is expected to have rain along with the amount of rain that is expected. The first statement is approximately the same as a probability forecast for each farm or plantation. For example, if the forecast calls for rain in 30 per cent of the Delta, each farmer may assume that his chance of getting rain is 30 per cent or about one out of three.

The accurate forecast of rain is one of the most important needs of Delta agriculture. In addition to the primary farm operations such as planting and harvesting which are dependent on dry weather, some of the secondary operations of farming in the area are especially sensitive to wet weather. Dusting and spraying of insecticides, fungicides, and

The agricultural weather observation station at the Delta and Pine Land Company near Scott, Mississippi.

A close-up of the above weather enclosure showing a pyrheliograph on white stand at right, evaporation pan with ground-level anemometer, standard instrument shelter containing thermometers and hygrothermograph, and rain gage hidden behind shelter.

herbicides are a vital part of agriculture in the humid Delta. Often, the decision as to whether to spray or not involves as much as a thousand dollars for each plantation; thus, if accurate forecasts can prevent just a few wasted operations, farming in the area has been made more efficient.

Wind speed is a part of the new forecast format and is a necessary consideration when planning dusting and spraying operations. In the fall, defoliant chemicals are applied to cotton plants in order that the leaves will fall off at the desired time. Most of these defoliants are dusted onto the fields in the evening and need a dew on the following morning to start their chemical action. Expected dew intensity is forecast; and again, if this information saves a few wasted applications of expensive chemicals, the agriculture of the area becomes more efficient.

In the summer and fall, the aviation forecast center at Memphis issues twice daily agricultural-aviation summaries for the Delta. These include ceiling and visibility forecasts which, when combined with the other information, give the large number of aerial applicators in the area specialized advisories on which to plan their schedules.

Specialized Observations

Ten weather stations in the Delta, as shown in figure 2, telephone daily reports of maximum and minimum temperature and 24-hour rainfall. These reports enable the forecaster to make a fairly detailed verification of his forecast almost immediately. This eliminates the feeling of shooting in the dark, that so often accompanies forecasts that cannot be verified for a month or two, if at all.

Daily measurements of evaporation and wind movement are part of the observations and will be useful in the study of agricultural-weather relations of the area. In the spring, a number of stations report soil temperature for the benefit of seed germination and emergence studies. During the fall, subjective estimates of dew intensity are reported; a vital part of the cotton harvest weather.

More complete observations are made at the Experiment Station in Stoneville. Yearround measurements of sunshine intensity and maximum and minimum soil temperature are recorded. In the fall the Forest Service maintains a fire danger measurement station as a part of the Stoneville observatory. During particular life stages of the crops, observations of a number of different weather elements are made in the field.

The agricultural weather station at the Delta and Pine Land Company near Scott, Mississippi, shown in figure 3, is part of the Delta observation network.

Communications

For a forecast to achieve its maximum usefulness, it must move from the forecaster to

the user with a minimum of delay. In the area of aviation weather, the quick transmission of forecasts and observations to the user is so commonplace that it is taken for granted —that is not always true in the area of agricultural weather however. If the pilot project were to have its maximum effect, a means of forecast distribution somewhat similar to the channels used in aviation weather had to be established.

The Weather Bureau installed a teletypewriter circuit from Jackson, through Vicksburg and Stoneville, to Memphis. Most of the news outlets in the Delta are now on the circuit and include nine radio stations, one television station and a newspaper (shown by the crosses on the map). In addition, the radio and television stations in Jackson and Memphis have the information available through their own local teletypewriter circuits.

Tunica county has an unique means of distributing weather information. There the County Agent's office is connected to the circuit and includes weather advisories along with its other services to farmers. An automatic telephone answering service is also part of the County Agent's program. Though the record of some 300,000 calls per day, as set by the automatic weather telephone in New York, is not in danger of being broken by Tunica county, the dollars and cents value of the decisions based on each call received in Tunica is probably greater than most other weather answering services.

To be most useful, an experiment such as this project must have lines of communication for information other than day-to-day advisories. The Delta Council of Mississippi, the National Cotton Council of America, and the Mississippi Extension Service have distributed information concerning the project. Also, they have contributed to the educational phase of the project by passing out considerable information explaining the nature of weather and weather forecasting.

Research

Research performed by the Delta Project has fallen into two groups: studies relating climatological records to agricultural practices, and studies relating plant development to the immediate environment as measured by current micrometeorological observations.

Under the first heading, the climate of the area has been analyzed and the probability of occurrence has been determined for certain important variables such as: rainfall, sunshine, temperature, frost and humidity. The Bioclimatological Section of the Office of Climatology analyzed evapotranspiration in the area. As another phase of research, the variation of these elements is related to the life cycle of the crops of the area.

The Short Range Forecast Development Section of the Office of Meteorological Research is studying rainfall scatter in the Delta and is developing an objective method of forecasting rainfall probability through the use of the electronic computor.

Cotton is at the mercy of the weather throughout its long growing life. The final phase, harvesting, is no exception. If the moisture content of seed cotton is too high at the time of picking and ginning, the grade and quality of the cotton will be lowered. Relative humidity has been found to be the greatest single control over lint moisture. Microweather observations in cotton fields have established the general pattern of relative humidity in the fields. One by-product of this study showed that defoliated fields average about an hour more "safe" picking time than fields with a leaf cover. In humid areas, this difference in humidity can make a significant difference in the price of the final product.

Conclusions

The project finished its first year of operation in October 1959. A preliminary evaluation by planters and agricultural specialists indicated that the project has been of help to the area. Even though a number of specific problems have been at least partially solved, the main benefit of the project is expected to be better understanding. The Weather Bureau will better understand the needs of agriculture and the agricultural specialists and farmers will better understand weather. To paraphrase Benjamin Franklin, and the motto of this booklet, we hope that the farmers of the area are becoming "more Weatherwise, rather than otherwise."

The Ice-Fall Problem

JAMES E. MCDONALD, *Institute of Atmospheric Physics, University of Arizona*

IT is a rather curious and apparently unexplained fact that from time to time in recent years masses of ice of the order of several tens of pounds have fallen out of the sky. This is the ice-fall problem.

Details of some one specific case of an ice-fall may be informative to the reader. The following case was that which first called my own attention to this peculiar problem.

Near midday, 16 November 1959, in Whittier, California, falling ice tore a 12 by 8 inch hole in the shingled roof of a residence and cracked plaster of the ceiling under the attic space. On investigation, pieces of ice estimated at an original total of about 25 pounds were found in the attic. Sheriff's officers gave the press the explanation that this was undoubtedly ice broken loose from deicing gear of some aircraft.

Reading a wire story on this Whittier ice-fall the following day, and being reminded that a similar event had occurred in Georgia two weeks earlier, I checked the hourly sequences for Los Angeles and Burbank airports for the 16th. From sunrise to sunset on that date there was not a single hour upon which *any* clouds were reported by either of these two stations near Whittier. Subsequent inquiry through a local Whittier newspaper confirmed the date and details of this event, so the lack of clouds was not due to any error of date. Inasmuch as aircraft icing of the unusual intensity that would be required to give deposits that might conceivably yield chunks of breakoff ice weighing anything like 25 pounds could only occur within quite heavy raincloud, it seems entirely impossible to explain the source of the Whittier ice-fall in terms of deicing gear action.

Apparently the subject of ice-falls has for several years been of interest to the National Investigations Committee on Aerial Phenomena (NICAP), as indicated in the NICAP request for ice-fall data made by its secretary, Mr. Richard Hall, in the August 1959 issue of this journal. My interest was aroused by the Whittier incident and the just-preceding case in Georgia where on 27 October 1959 a piece of ice estimated at 50 pounds plummeted down to earth "with a loud whistling noise," barely missing a farmer and producing a crater several feet in diameter. I wrote NICAP requesting data on other such cases. I was kindly sent not only dates and localities, but copies of original newspaper accounts from local papers plus copies of reports on chemical analyses of meltwater in several cases and copies of a number of official British commentaries on similar events in England. These data seem to me to imply that the ice-fall problem is worth rather more scientific attention than it seems yet to have been given.

In the accompanying table on page 111 I have put into chronological order the thirty ice-falls for which the NICAP clippings and data seemed reliable. In a few additional cases the circumstances were either inadequately reported or seemed explainable in other ways (e.g., ice-chunks found on a roadway might have been discarded by a milkman, or otherwise dropped). The table gives the date and locale of the ice-fall plus remarks on relevant circumstances. The points of principal meteorological interest in the table are contained in the columns headed A-C.

A cross in column A means that the ice-fall in question occurred at a place and on a day during which a frontal passage occurred. A cross in column B implies that in the 24-hour period ending at 0100 EST on the calendar date following the date of the ice-fall precipitation between a trace and 0.10-inch fell at or within 100 miles radius of the locale of the ice-fall. A cross in column C implies occurrence of a total of over 0.10 inch precipitation for the just-cited time and space. All data were read from U. S. Weather Bureau Washington Daily Weather Maps.

Occurrence of heavy aircraft icing requires high subcooled cloud liquid water content and large drop sizes. Frontal zones are notoriously conducive to such conditions. Never-

Date	Locality	A	B	C	Remarks
2/18/53	New York, N. Y.				50 pounds fell near LaGuardia Field.
4/15/54	New York, N. Y.		x		10 pounds fell near Idlewild.
6/10/54	Bath, Pa.	x			"Large chunk."
1/3/56	Jefferson, Pa.	x			25 pound chunk fell from clear sky, honeycombed structure.
3/18/57	Los Angeles, Cal.		x		Chunk, estimated at 50 pounds, struck roof of house under final approach to airport, shattered into fragments of which one broke a window.
4/4/57	Rockville Center, N. Y.		x	x	Large piece penetrated roof of residence.
7/30/57	Bernville, Pa.	x			Two chunks, estimated at about 50 and 25 pounds, respectively, fell near a farmer working in a field. Appeared to consist of fused spheroids of ice. Chemical analysis gave 106 ppm hardness and high total solids. Unusual rumblings throughout surrounding counties reported to police at roughly the same time.
8/14/57	Shamokin, Pa.				About 25 pounds fell from clear skies. Structure similar to Bernville ice. Analysis: 128 ppm hardness, high solids.
8/27/57	Camp Hill, Pa.	x			About 20 pounds, flat cake, prismatic crystals, neutral ph, "no solids, no hardness."
9/8/57	Chester, Pa.	x			Chunk estimated at 100 pounds damaged slate roof. Cloudy, high alkalinity, high solids.
9/10/57	Philadelphia, Pa.	x	x	x	
9/12/57	Philadelphia, Pa.	x	x		20 pound piece penetrated warehouse roof, shaking building. Fragments described as milky with brown spots in it. High solids, hardness, alkalinity.
9/18/57	Annandale, N. J.				40 pound chunk, 3′ × 1.5′ × 0.3′, found in field by road crew. Fall not witnessed. Columnar structure, no alkali.
9/25/57	Yeadon, Pa.	x			
10/11/57	New Kensington, Pa.				
11/6/57	Philadelphia, Pa.		x		Piece of about 10 pounds struck roof and shattered.
11/12/57	Belle Mead, N. J.				Football-shaped piece a foot in diameter found on lawn.
11/25/57	Long Island, N. Y.				"Sizeable chunk" fell on home roof just after occupant heard aircraft fly over.
1/6/58	Fountain Hill, Pa.				Piece nearly hit pedestrian. Ice filled with bubbles, no layer structure.
1/18/58	Freemansburg, Pa.		x		Fell with swishing sound near pedestrians, all fragments clear of bubbles.
3/26/58	Whittier, Cal.				Piece about 50 pounds fell near man and son flying kite. Aircraft had just passed over.
3/28/58	Firestone Park, Cal.		x		About 25 pounds hit roof and shattered, immediately following aircraft passage.
9/2/58	Madison, N. J.				70 pound chunk tore three foot hole in residence roof and continued through attic ceiling into kitchen, splintering furniture there. Aircraft passage reported immediately before.
			x		
9/18/59	Amherst, N. Y.				15 pound piece fell near two boys. Buffalo City chemist analysed meltwater and found only 2 ppm hardness.
10/26/59	Toccoa, Ga.	x	x		40 pound piece fell with hissing sound 10 ft from farmer, creating crater the size of an automobile wheel. Ice milky, surface pitted like meteor. Chemist said composition matched river water in southeastern United States.
10/30/59	Cleveland, O.	x	x		Total of seven separate ice falls throughout city. One tore a 15-inch hole in roof and then in upstairs ceiling. Another about size of basketball fell with noise like a freight train near two golfers. No details on the other five. Chemical analysis suggested similarity to water in parts of New York State but "definitely not Cleveland water."
11/2/59	Cleveland, O.		x		10 pound fragment observed to fall by workman nearby.
11/3/59	Cleveland, O.		x		Piece 2 inches thick and about 9 inches across, yellowish, found on lawn but not observed falling.
11/16/59	Whittier, Cal.				Piece estimated at 25 lbs. tore hole 12″ in roof.
11/22/59	Miami, Fla.				Home occupants heard loud thud outside but did not until few hours later find chunk of ice "about the size of a toaster" in yard. Checked FAA and found no flights in area at time. Same night another Miamian found a slab 9″ across and 6″ thick, "diamond-clear," but not observed falling.
30 entries	Total	10	13	2	

A—Frontal passage on day of occurrence.
B—Trace to 0.10″ rainfall in 24 hrs. after 0100 of calendar date of ice fall within 100 miles.
C—Over 0.10″ of rainfall.

James M. Presley of Smyrna, Georgia, holds piece of ice found along side of Highway One on 31 October 1959. "Ice falls" had occurred at Toccoa, Ga., on the 26th and at Cleveland Ohio, on the 30th. *Atlanta Journal* photo by Bill Wilson.

theless, many fronts bring little precipitation, so actual occurrence of precipitation at the ground is rather more conclusive evidence that icing conditions might have prevailed aloft (above the freezing level) at a given station on a given day. Finally, icing of the sort required to explain the kinds of ice-fall weights to be found in some of the "Remarks" section of the table really requires that vertical motions and liquid water contents be so large as to yield more than just a few hundredths of an inch of precipitation. Thus, we may say that a cross in column A is weak evidence that an ice-fall might be explained in terms of knockoff ice from deicing gear, one in column B is rather better evidence, and a cross in column C is probably the best indirect evidence of all, albeit not conclusive. By allowing a radius of 100 miles about the site of the ice-fall, the possibility that icing accumulated when the aircraft was uproute from the site and did not melt loose until it reached the site is allowed for reasonably well.

There are seen to be 10 crosses in column A, 13 in B, and only 2 in C. Thus the evidence is very strong that in a majority of these 30 ice-falls it is quite out of the question to invoke aircraft icing of any ordinary type to explain the reports. In only about six per cent of all cases would heavy icing in the ice-fall area be at all likely. In about a third of all cases, no cloud systems were closer than five or six hundred miles of the ice-fall site.

Indeed, most currently operating aircraft do not use the type of pneumatic deicing boots that might be imagined capable of

yielding chunks of the reported size. (It must be remembered that these are independently reported incidents and that most persons will have rather reliable notions of the volume of, say, a 25-pound cake of ice.) Thermal deicers operate to *avoid* at any and all times the accumulation of more than a few millimeters of ice-coating over the protected surfaces. Finally, as was noted by one airways official, it would be difficult to imagine how an aircraft could even fly if generally iced so heavily as to be the source of such large pieces of ice as are involved in many of these occurrences. In all, we may conclude that knockoff ice from aircraft deicing gear simply cannot fit the known circumstances of most ice-fall incidents.

Nevertheless, some kind of aircraft source remains the most plausible explanation, so we should search further. Needless to say, jettisoning of solid ice from airliners is never practiced. But an hypothesis that has been advanced and apparently officially considered by airways officials to account for ice-falls involves disposal of liquid water from airliners. Although all water used in aircraft toilet systems must, by law, be retained in flight, there are a few types of commercial air transports that do exhaust water from cabin and galley washbowls while in flight. The suggestion has thereby been made that perhaps the washbowl exhaust water freezes at or just behind the exhaust port while the plane is flying in below-freezing temperature, builds up to a load of several tens of pounds, and then dislodges, possibly after let-down to warmer levels.

I have not made any complete inquiry concerning the aircraft types that thus release washbowl water in flight, but have determined that neither the widely-used DC-6 and DC-7 airliners nor the Convairs do. Apparently Stratocruisers and Constellations do release waste-water while airborne. In the Constellation, the water is usually exhausted through a venturi that emits the water as a fine spray from the rearward-directed tip of an L-shaped venturi whose orifice is a foot below the fuselage skin amidships. The tip of this venturi sometimes ices up bulbously, but apparently never develops thicknesses much in excess of the size of a man's fist. However, some Constellations do not have these venturis, but simply release it from an orifice flush with the skin, and these reportedly form ice accumulations just aft of the opening. The largest accumulations, under heavy icing conditions, were described by one airline pilot who flies Constellations as only a few inches thick and a foot or so long, which is too small to explain all ice-fall cases.

Despite the above objections to the waste-water hypothesis, this source of ice-falls is strongly indicated in 7 out of 27 reported British ice-falls summarized for NICAP by the Ministry of Civil Aviation. The strong evidence is simply that in these seven cases the ice was found to be strongly perfumed and had fragments of tea leaves and sugar and milk within it. In two of these instances Constellations were reported to have passed over the ice-fall site near the time of the fall.

An odd feature of the accompanying table is the seemingly non-random geographical distribution of ice-fall sites. Why should so large a fraction fall in a band only about two hundred miles long from southeastern Pennsylvania to Long Island? About two-thirds of the 30 cases cluster in this one small area. Four cases in the Los Angeles area make that the poor second, unless we weight Cleveland for its one day's total of seven occurrences all on 30 October 1959. Could the high concentration in the Pennsylvania-Long Island band mean that some airline operating only in that area is or was using equipment of such configuration as to form heavy waste-water ice accumulations rather frequently? Or could it be that this is the let-down area for transcontinental flights terminating in New York City? Long-distance flights of large airliners would, of course, be more likely to yield sizable waste-water ice accumulations than short flights of airliners carrying small numbers of passengers. These possibilities might well be looked into by some reader familiar with this area's air activities.

Another seemingly non-random feature of the table is the bunching together in time of fully half of all the 30 cases into a period of less than six months from 30 July 1957 to 18 January 1958. And most of these occurrences involved localities in the Pennsylvania-Long Island band, to add mystery. Here again, readers living and working in the area may be able to shed interesting light on the problem.

In some of the public speculation on the ice-fall problem that is to be found in the

local news accounts from which the above tabulated data were taken, it is loosely suggested that "jet streams" bearing hailstones aloft might account for the phenomena. Putting aside the fact that the meteorologist's "jet stream" blows horizontally and not vertically, and noting that in at least nine-tenths of the tabulated cases the weather conditions simply could not have led to hail formation, it remains of physical interest to discuss not the upward air current required to bear one of these large chunks aloft but rather the terminal velocity of free fall that such pieces might attain if they are, in fact, falling off aircraft.

As a sufficient illustration, we may consider a 10-pound spherical mass of ice, i.e., one rather small compared to the majority of the ice-falls for which weights are available in our table. Such an ice sphere will have a diameter of slightly over 8 inches. Computation shows that it would only be at terminal speed (speed just high enough that the upward-directed aerodynamic drag force just equals the downward-directed weight force) after it had accelerated to a downward velocity of about 535 mph, assuming sea level air density. (The above speed was computed assuming a drag coefficient of 0.15 to match the high Reynolds number here associated with terminal velocity.) It is easy to show that, even if the ice sphere were allowed to fall from rest in a vacuum, it would not gravitationally accelerate to so high a speed until it had fallen through almost 10,000 ft; so, in the actual presence of the very air that imposes the hypothesized terminal fall conditions, it would have to fall farther than 10,000 ft before attaining quasi-steady speed. A more exact solution than the above is not difficult to obtain, but the above will suffice to show that it is quite likely that these ice-falls involve potentially lethal missiles (if roof-damage leaves that at all in doubt).

If it is in fact true that they originate as waste-water icing on aircraft or as some other kind of aircraft icing not here considered, they ought to be considered a hazard to life and be given much more thorough investigation. And if they can be shown to be beyond engineering control because of *not* originating on aircraft, then the ice-fall problem becomes very much more intriguing than ever.

I would suggest, then, that any readers who have now or in the future acquire first-hand information on ice-falls or who can merely supply local newspaper accounts thereof, should communicate these to NICAP, as urged in the August 1959 *Weatherwise*.[1] At the moment this seems the best means of centrally collecting ice-fall data. It should be clear from the preceding discussion that any reader who reports an ice-fall should make every effort to secure information on types of aircraft operating nearby at time of the fall, and should also report all weather conditions relevant to the possibility of occurrence of ordinary aircraft icing. Certainly it is to be hoped that those federal airways agencies whose responsibility it is to consider the safety problem implied in the waste-water hypothesis will also undertake studies; but for the present we seem to have here a good problem for the cooperative efforts of amateur

[1] NICAP address: 1536 Connecticut Ave., N.W., Washington 6, D. C.

(*Continued on page 132*)

Kirk Sigmund holds "ice fall" which he and a companion saw drop from the sky at Amherst, N. Y., near Buffalo on 18 September 1959. *Buffalo Courier Express* photo.

Atmospheric Phenomena at a Sunrise Total Solar Eclipse

JOHN W. STEWART, *Department of Physics, University of Virginia, Charlottesville, Virginia*

THE total solar eclipse at sunrise on 2 October in eastern New England afforded an opportunity for the observation of unusual atmospheric effects. See *Weatherwise*, August 1959. In spite of the lingering cloudiness from Hurricane Gracie which prevented any view from the ground of the eclipse itself, a number of interesting observations were made.

At a sunrise eclipse, the moon's shadow cone approaches the observer from nearly overhead. It darkens the upper atmosphere before it reaches the surface of the earth. At the end of totality the shadow "drops into the ground" and disappears abruptly. At a sunset eclipse the reverse occurs. This vertical motion of the shadow gives rise to several phenomena which are not observed at eclipses occurring with a high sun.

On last October 2nd the moon's umbra, extending nearly due east and west, approached an observer in Massachusetts from about 24° south of the zenith, at a speed of greater than 2,000 miles per hour. The shadow cone was approximately 35 miles in diameter, and tapered slowly from east to west. For the purposes of the present discussion it may be regarded as cylindrical. Fig. 1 shows the relation of the shadow to the ground (not to scale) just before and during totality for an observer O in eastern Massachusetts.

Aside from the spectacle of the eclipse itself and of the solar corona, the phenomena of interest included the following: (1) Dawn reversal, (2) Asymmetry of illumination before and after totality, (3) "Red tunnel," and (4) Appearance of the moon's shadow in the sky.

The author with his parents had planned to observe the eclipse from the highest point of land on Marblehead Neck. However, bad weather on the coast and the last minute promise of some improvement to the north led to a change of plans. We shall always regret not having seen the horns of the 80 per cent eclipsed crescent sun rise nearly upright out of the sea.

Although the clouds remained thick over the entire eclipse track until well after sunrise, from a pasture hilltop 4 miles northwest of Nashua, N. H., and 2 or 3 miles inside the northern limit of totality, we were fortunate enough to have narrow strips of clear sky near our northern and western horizons. Overhead there was thinning altostratus, and to the east heavy stratocumulus with lower

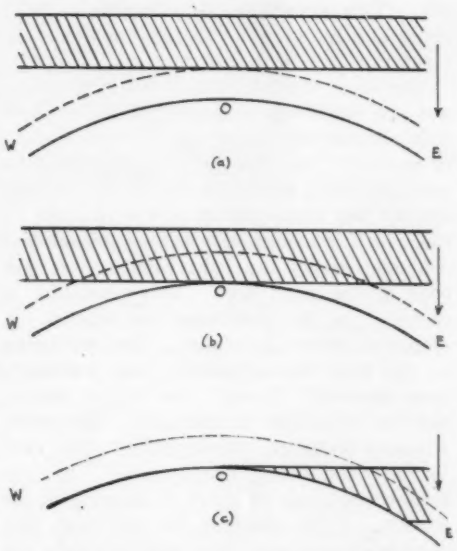


FIG. 1. Schematic diagram of the moon's shadow at a sunrise total solar eclipse. The ground sunrise point is at 0. The dotted circular arc indicates the indefinite upper limit of atmosphere (perhaps 20 miles high) dense enough to reveal the outline of the shadow. The curvature of the earth is shown much exaggerated in relation to the thickness of the atmosphere and to the shadow diameter. (a) The shadow is just entering the atmosphere, perhaps 30 seconds before totality. Darkening appears overhead. (b) The eclipse becomes total at the ground. (c) Totality ends at the ground.

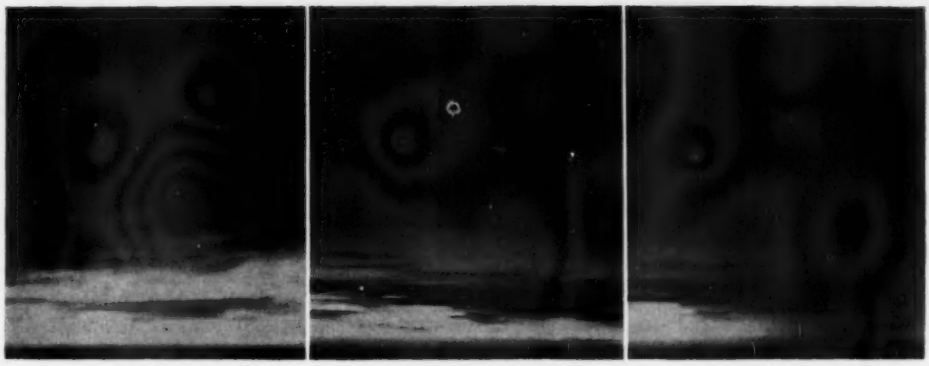
scud and rain showers. We arrived at this site at about 0625 EDST, 25 minutes before totality. At about this time the previously normally brightening cloudy dawn briefly "held its own" and then reversed as the moon was encroaching more and more upon the face of the as yet unrisen sun. From 0630 on the general illumination of the landscape gradually decreased. During the last minute or so before totality (0650) the effect from our vantage point was as if the house lights of a gigantic theater were being dimmed. During this period the shadow was falling unseen through the air above the clouds (Fig. 1a). As the eclipse became total the light stopped fading and remained constant. One could barely read a wristwatch. We could not tell the exact instant at which totality began. At the end of totality the landscape brightened much more rapidly than it had faded as the shadow "went to ground" (Fig. 1c). This asymmetry of illumination was noted also by several observers on the rainy coast.

The most striking feature of this eclipse was the surprising reddening of the western strip of clear sky during the 25 or so seconds of totality. See also John Q. Stewart, *Sky and Telescope*, December 1959. Just before totality this clear strip as well as the one to the north assumed the saffron-yellow hue characteristic of the light coming from the edge of the sun's disk. This coloration is observed in the illuminated air around the umbra at all total eclipses. The reddening to the west has apparently not previously been reported. It was a red of high saturation but rather low illumination. The northern strip remained saffron-yellow. Our view to the west during totality (Fig. 1b) was through hundreds of miles of air lying in the shadow. Light reaching the eye from this direction must have been scattered into the line of sight from the sides and then have traveled a long distance through air. While short wave length blue light is much more readily scattered than long wave length red, the long transmission path through air would effectively absorb all but the red. One wonders if the eclipsing moon seen in the opposite direction would also have appeared red during totality. The airborne observers who were lucky enough to have seen the eclipse itself did not report any such effect. Presumably they were above enough of the atmosphere so that the effect would not have been conspicuous. The next chance to look for the red tunnel from a reasonably accessible land location will be 20 July 1963 on the east coast of the island of Hokkaido, Japan.

We had hoped to observe the outline of the moon's shadow as it descended through the atmosphere. The clouds prevented this at all ground locations within the path of totality, but several observers west of the sunrise point did see it. Figure 2 shows a sequence of photographs taken by a Naval Research Laboratory group headed by Dr. Richard Tousey. This group had hoped to observe the zodiacal light closer to the sun than is normally possible. Unfortunately clouds interfered. The camera was facing east from a plane 15,500 feet above Windsor, Ontario, some 300 miles west of the sunrise point. The dark cone of the shadow is clearly visible in the third picture, which was taken at the instant of totality in Massachusetts. Figure 1b shows how the shadow can be seen in the eastern sky from a considerable distance west of the ground sunrise point.

Ground observations throughout New York and western New England were seriously hampered by partial or complete cloud cover. In advance of the eclipse Mr. William H. Glenn of the Amateur Astronomers' Association of New York City had prepared questionnaires on the appearance of the shadow in the sky. These had been distributed widely in and to the west and south of the eclipse track. About 20 replies were received, all but three negative. The general cloud cover prevented the hoped-for determination of the maximum distance from the ground sunrise point at which the shadow could be seen. This distance is at least 300 miles, and with perfect sky conditions would probably be considerably greater.

A group of observers from the Mt. Hermon School were at Crag Mountain, Massachusetts, near the extension of the central line 14 miles west of the sunrise point. They reported a "parabola shaped grayish-black shadow" in the sky. They had clouds near the eastern horizon. At Mt. Vernon, New York, Mr. John Bortle reported seeing a "smokey gray shadowy half-disk about 30° north of east. It had a striking similarity in color to gray chimney smoke but its shape



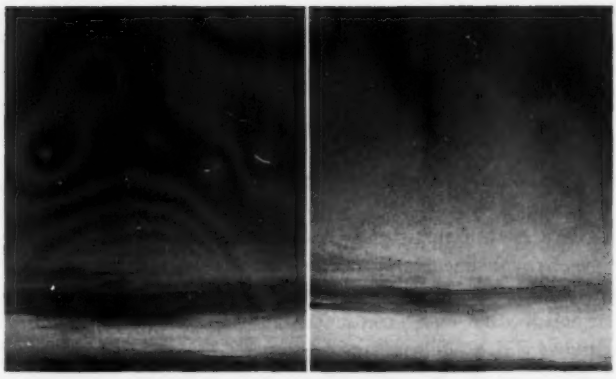


FIG. 2. Series of photographs from the air over Ontario taken before, during, and after totality. The five photographs were taken at 0641, 0649, 0651, 0653, and 0657 EDST. The shadow cone is clearly visible in the top middle picture, taken during the period of totality as seen in Massachusetts. Note the edge of the cloud deck low on the eastern horizon. Official U. S. Navy photos.

was unmistakable. Its boundaries were not sharply defined. It was in excess of six degrees in diameter, and slowly descended as we watched." Mr. Bortle states further that a dark cone extended to the west from this half-disk along the northern horizon. The third positive report was from Mr. Sidney R. Weeks of Schroon Lake, N. Y. He stated that "the entire east to south quadrant darkened as though twilight were falling." These descriptions are all consistent with what one might have expected to see at these locations.

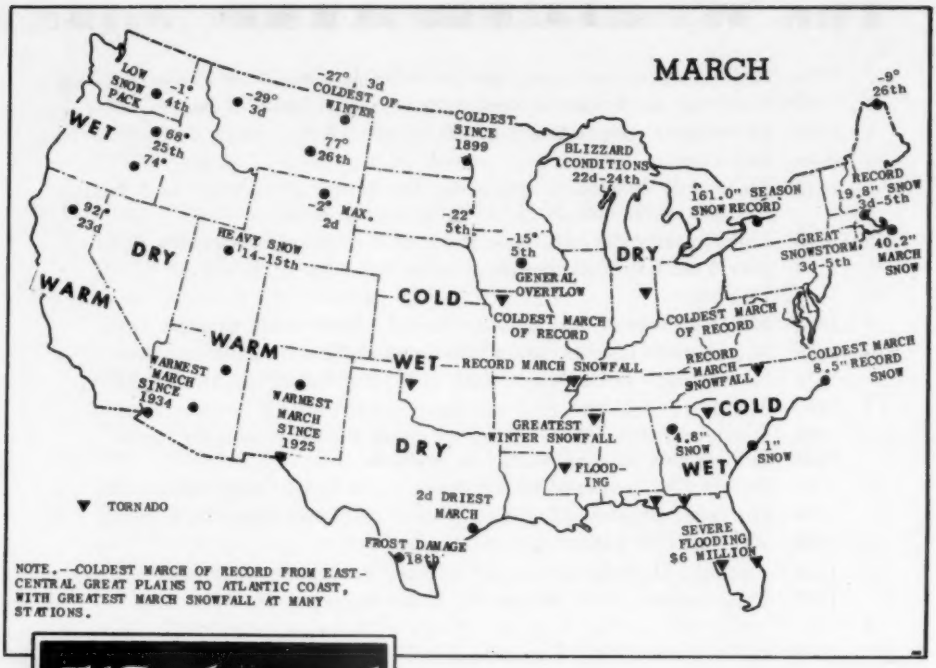
The last three total solar eclipses visible in the United States have all occurred near sunrise. In 1945 weather conditions in Idaho were good for observing these atmospheric effects, but wartime travel restrictions prevented any serious attempts. In 1954 cloudiness was extensive in Colorado and Nebraska. On both occasions the shadow was seen from up to 300 miles west of the sunrise point. Unfortunately, the next low sun total eclipse visible in the United States will not occur until 2044, at sunset in North Dakota.

The WEATHER PAST / July

1	1876	Douglas, Wis.—Ice field 25 sq. mi. still at head of Lake Superior.
2	1953	Nebraska.—Severe hail Kimball-Banner-Cheyenne Cos.—$6 million.
3	1863	Gettysburg.—Partly cloudy, 87°, SSW–1, during Pickett's Charge.
4	1776	Thomas Jefferson paid for his first thermometer and signed Declaration of Independence: 76° at 1300, cloudy, at Philadelphia.
	1956	Unionville, Md.—greatest U. S. rainfall in one minute—1.23″.
5	1871	Tornado at De Soto, Neb., blew railroad cars off track—heavy hail.
	1891	Rapid City, S. D.—Hail killed 16 horses, injured many others.
	1916	Mobile's worst modern storm—107 mph, 28.92″, tide 11.6′.
6	1928	Famous Potter, Neb., hailstorm—stone measured 5.5″ dia., 17″ circum., wt. 1.5 lbs—"largest officially recorded" (Flora).
	1936	121° at Steele—highest ever recorded in North Dakota.
7		
8	1816	Waltham, Mass.—frost on 8–9th in low places—44° at sunrise.
9	1860	"Hot blast" in Kansas—115° Ft. Scott & Lawrence, 112° Topeka.
	1936	New York City's absolute highest (Battery)—102.3°.
10	1913	Greenland Ranch, Calif.—134°, reputed highest ever in U. S.
	1936	Great hot day in East.—Pa. 111°, N. J. 110°, W. Va. 112°, Md. 109°.
	1955	Heavy one-minute rain at Jefferson, Iowa—0.69″.
11	1951	Worst flood ever raging in Kansas-Missouri—41 lost—$1 billion.
12	1818	Woodbury, N. J.—103°, "hottest since Battle of Monmouth in '78."
	1842	Eastern N. Carolina—severe hurricane—30 ships on Hatteras.
13	1859	Severe squall line Mass. to Pa.—tornadic-type damage N. Y. City.
14	1886	Los Angeles' greatest 24-hr July rainstorm—0.24″ fell.
15	862	Bishop Swithin died—continued rains delayed burial for 40 days.
	1799	Famous S.E. Conn. hailstorm—stones 2–3″ dia.—monograph printed.
16	1945	Alamogordo, N. M.—first atomic bomb exploded—weather clear.
17		
18	1680	Tornado at Cambridge, Mass., described by Rev. Increase Mather.
	1889	Cloudburst at Rockport, W. Va.—19″ in 2 hrs, 10 min.
	1942	Deluge at Smethport, Pa.—30.70″ in 6-hrs, 34.30″ in 24-hrs.
19		
20	1930	Washington, D. C.—106° highest ever recorded.
21	1911	Painter, Wyo.: +10°, lowest ever for U. S. in July.
22		
23	1788	Severe hurricane—eye described by G. Washington over Mt. Vernon.
24	1890	Tornado at Lawrence, Mass., killed 8 and injured 59.
	1936	Near Alton, Kansas—121° highest ever recorded in Wheat State.
25	1891	Los Angeles heat wave at 109°—also 103° on 24th, 100° on 26th.
26	1819	Twin cloudbursts of 15″ struck almost simultaneously at Catskill, N. Y. & Westfield, Mass.—flash floods—enormous erosion.
	1875	Erie, Pa.—wind storm (tornado?) killed 134 persons—$\frac{1}{2}$ million.
27	1926	Hurricane close to Jacksonville—damage East Florida $2.5 million.
28		
29		
30	1933	Hurricane moved inland at Ft. Pierce, Fla.—no great damage.
31	1769	Scituate, Mass.—hail fell 12″ deep, remained on ground 30 hours.
	1839	"Yale" tornado at New Haven—investigated by faculty & Redfield.

The WEATHER PAST / August

1	1831	Redfield's first hurricane paper published in *Amer. Jour. Science.*
2	1795	Hurricane drove Spanish fleet of 18 vessels on Hatteras shoals.
3	1898	Philadelphia's worst thunderstorm—5.84″ fell in 2 hours.
4	——	Dog Days.
5	1843	Spectacular cloudburst on Chester Creek near Phila.—16″ in 3 hours—also at Newark, N. J., 15″+ by bucket survey.
6	1918	Phila.—sticky day, dry bulb 100°/wet 83°—discomfort index 79.4.
7	1918	New York City's warmest day: mean 92°, max 102°, min 82°.
8	——	Dog Days.
9	1878	Major tornado at Wallingford, Ct.—30 killed—much damage.
10	1856	Isle Derniere disaster, storm tide drowned 250 Louisiana socialites.
	1936	Hottest day ever in Ark. (Ozark 110°) and La. (Plain Dealing 114°).
11	1860	Mobile—first of two 1860 hurricanes—tide only 18″ from record.
12	1778	Rhode Island hurricane prevented major British-French sea battle.
	1936	Hottest ever in Texas—120° at Seymour.
13	1795	Second 1795 hurricane caused floods Va. & N. C.—very wet summer.
	1955	Hurricane Connie—83 mph on coast, 6 tornadoes inland N. Carolina.
14	1936	Kansas City's hottest day—113°.
15	1761	President Holyoke of Harvard adopted Fahrenheit thermometer scale.
	1787	Long tornado: New Britain, Ct. to Rochester, N. H.—150 miles.
16		
17	1885	Amos, Calif.—130°, highest ever in U. S. for August.
	1915	Another Galveston hurricane and flood tide—275 lost—$50 million.
18	1779	Hurricane eye over N. Orleans—Dunbar correctly described vortex.
19	1788	Spectacular small cyclonic storm, great havoc NYC to N. Hampshire.
20	1939	Tuckerton, N. J.—14.81″ in 24-hrs exceeded all state records.
21	1883	Tornado at Rochester, Minn.—31 killed.
	1918	Tornado at Tyler, Minn.—36 killed.
22	1816	Damaging light frosts low places interior N. England to N. Carolina.
	1851	"Harvard" tornado—W. Cambridge-Belmont-Arlington-Medford.
	1875	Destructive frosts in Midwest on 21–23rd damaged crops.
23	1683	Hurricane in Virginia and great flood on Connecticut River.
	1806	Great hurricane swept Atlantic Coast—deluge est. 18″ Cape Cod.
24	1854	"The Great Drought"—all N. Y. State rainless for 16–24th.
	1906	Cloudburst at Guinea, Va.—9.25″ in 40 minutes.
25	1635	Great Colonial Hurricane—same stature as 1815 & 1938—same track as 1944—tide rose 20′—vividly described by Winthrop & Bradford.
	1814	"Hurricane" hit Washington when in British hands—trees uprooted.
	1885	Killing frost at Fargo, N. D., ended short 78-day growing season.
	1910	Bowen, Mont.: +10°, lowest ever for U. S. in August.
26	1949	Delray Beach—1 of 6 *great* Florida hurricanes—28.17″—153 mph.
27	1813	Severe hurricane at Charleston—tide 18″ higher than in 1804.
	1881	Georgia hurricane—335 lost—severe at Savannah & Carolina coast.
	1893	Storm tide submerged S. C. coast—1000 drowned—$10 million.
28		
29	1816	Killing frosts again damaged corn in northern New England.
30	1839	Coastal hurricane caused snow at several places—Catskills white.
	1954	Carol swept eastern New England—60 lost—$450 million—120 mph.



Weatherwatch

Data by Office of Climatology, USWB.

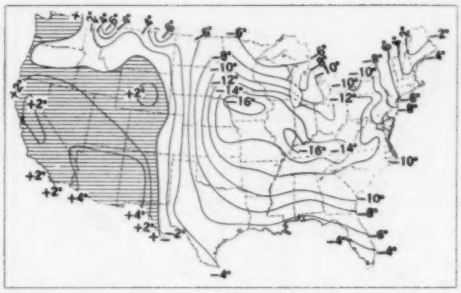
The Great Temperature Reversal: March to April

DAVID M. LUDLUM

On the first day of March a vast area of high pressure overlay a greater part of North America with a ridge line extending from eastern Alaska all the way to the Gulf of Mexico and the coast of the South Atlantic States. Arctic air occupied all this vast region; in the United States only the far Southwest (coastal California, southern Arizona, and southwestern New Mexico) lay outside its reaches. Zero temperatures extended southeastward to Indiana, southward to Missouri, and southwestward to southern Colorado, and the freezing line rested just north of the Gulf Coast. The core of the cold air mass stood over the Prairie Provinces of Canada where temperatures read close to −20° and pressures ranged above 1048mb/30.95″. Through this dome of bitter cold air snow flakes commenced to filter early on the 1st from Montana southeastward to Oklahoma, and they gradually spread with steadily increasing intensity to all sections east of the Rockies with the exception of the Deep South.

Such was the beginning of the memorable month of March 1960. More records for sustained cold and for persistence of snow cover were set than in any other March of modern record. Stations with century-old tabulations entered new chapters for March extremes. In central parts of the country, from Kansas and Iowa eastward to the Carolinas, it was the coldest March ever experienced. In many diverse locations March proved colder than the preceding February, or it was the coldest month of the entire winter season. At northeastern and southeastern points along the Atlantic Coast it was the snowiest March of record. Much of southeastern New England had its deepest single snowstorm in modern times. In the central Plains snow accumulated to record depths at places, and at others the number of consecutive days with snow on the ground reached new figures.

It will be recalled that winter commenced early this season. In the northern Plains at mid-November the mercury had plummeted to all-time lows for any November, and heavy snows had spread across the Great Divide. November proved colder than December in much of the north central area, in many places the first time in history for this thermal juxtaposition. And now with record cold in



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

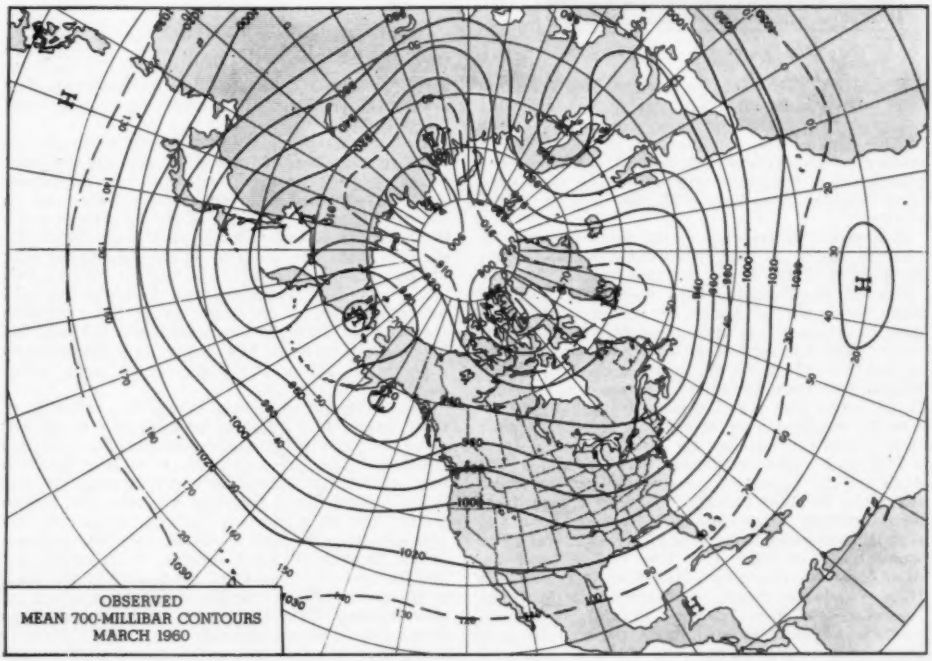
Total Precipitation in inches. USWB chart.

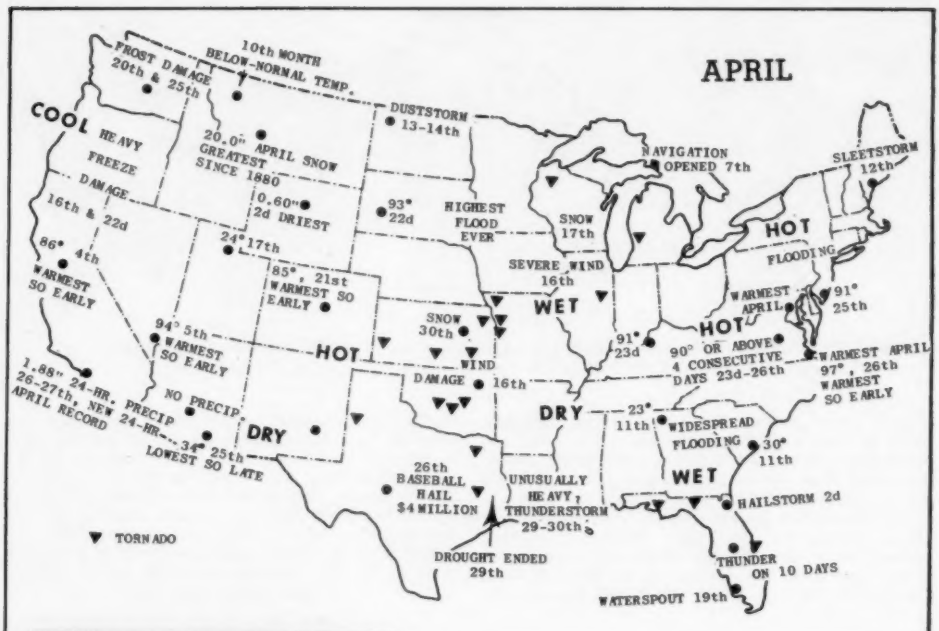
March, some stations had lower average temperatures in March than in February. Thus, the uneven winter season of 1959–60, commencing unusually early and continuing unusually late, extended for an unprecedented number of days.

As the weather pattern evolved for the month, a major battle for dominance developed between rugged Arctic air from the interior of Canada and Alaska and mild, but determined, maritime air from the Pacific Ocean. When the month opened, the battle front extended from northern California in a loop to New Mexico with Pacific air holding only a relatively small beachhead in the extreme Southwest. Elsewhere winter was in full possession of the air space. The central and southern part of the battle line, soon aided by a swift westerly flow at low latitudes and a building high pressure ridge over the Plateau, gradually pushed eastward to the Great Divide. By the 6th warm air on the northern flank,

(*Continued on page 125*)

The upper-air map below shows the pattern of air flow for March at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.





Weatherwatch

Data by Office of Climatology, USWB.

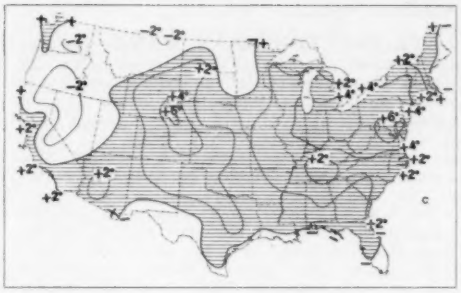
CIRCULATION—April opened wearing a weather face entirely different from that of the preceding wintry month. A major polar trough overlay the central part of the continent in company with a marked surface depression in the central Plains. The presence of a trough in this position on most days of the month was to provide the key to April's weather.

Seldom do we experience such a reversal in temperature regime as took place between March and April. Practically all of the area east of 100° W (Bismarck-Goodland-Del Rio) meridian experienced *much below* normal March temperatures. In April most of this area was *above*, and from Illinois eastward to the Atlantic a large section was *much above* normal. To illustrate the amazing reversal, March 1960 at downtown Richmond, Virginia, was the coldest of record with a 12.8 degrees deficit. April 1960 was the warmest ever experienced at the Virginia capital with the mercury 4.6 degrees above normal.

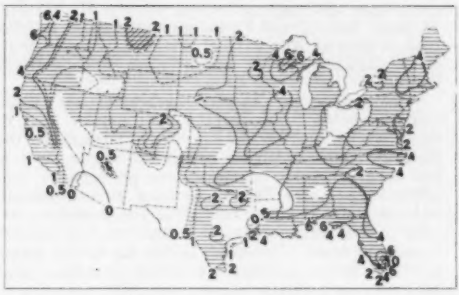
The most significant change between March and April on the upper-air flow charts can be found along the Atlantic Coast. The deep trough from Newfoundland to the Gulf of Mexico in March had all but disappeared; only a small remnant was to be found north of 45°. Off New England and the Atlantic States the trough had filled, the Bermuda High extended westward, and a southwesterly stream controlled air flow bringing tropical air masses northward. Southeastern Canada, the rendezvous of anticyclones in March, now had below normal pressures, a fact which steered the southwesterly flow around the periphery of the Bermuda High into the Northland.

With the disappearance of the Eastern trough, the main pressure feature shifted to the mid-continent where on most days of the month a low pressure structure stretched from Ontario southwestward to Texas, putting all areas east of the Mississippi River in the warm sector. The greatest temperature departures from normal came in the Middle Atlantic States. At Washington, D. C., after a variable two weeks with both warm and cold days, the hot spell set on the 14th to continue through the 27th with only one day during the two-week period having below normal readings. On many days the mercury averaged as much as 20 degrees or more above normal.

To the west of the central trough at a rather short wave length, high pressure maintained a mean axis along the 118° W (Edmonton-Spokane-Los Angeles) meridian. The pressure contours in the northern part of the ridge sloped fairly steeply poleward, but in the United States the ridge was relatively flat to present less of a blocking feature. Numerous depressions from the Gulf of Alaska were able to move inland through British Columbia, Washington, and Oregon, and push eastward, deepening all the time, to the central Plains. South of this storm track air flow, coming from the south or southwest, kept temperatures above normal along the California coast, over Arizona, and northeastward to Wyoming



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

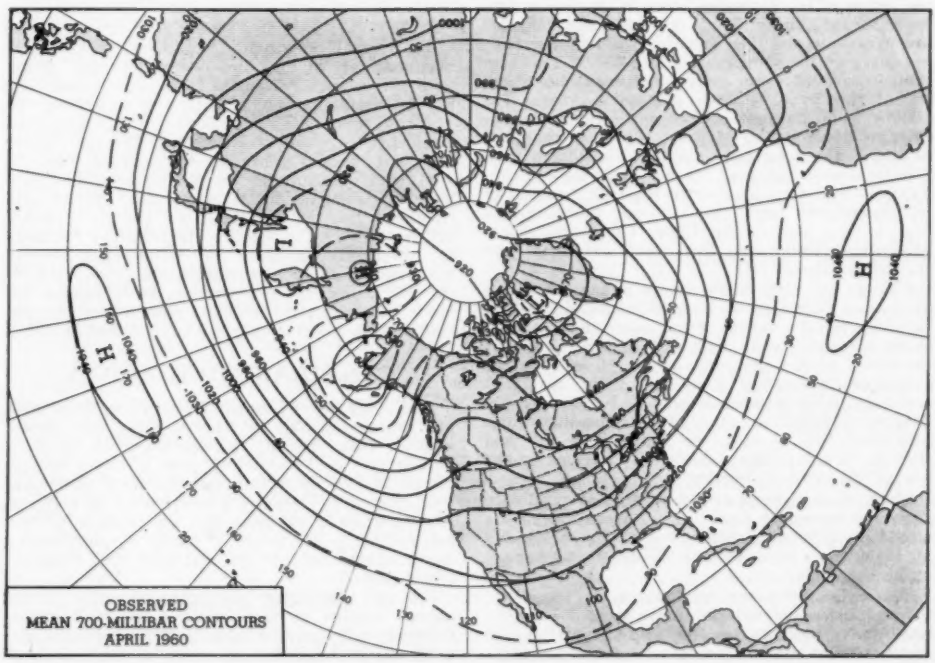
—in eastern Colorado and adjoining areas it was *much above* normal for a very warm early springtime in the Rockies. To the north of the main storm track, where cold air was occasionally pulled down from western Canada in the wake of the depressions, temperatures ran close to normal and a bit below.

EARLY WESTERN HEAT SPELL—California and most of the Southwest were treated to a mid-summer blast of heat early in April. Downtown Los Angeles had 80° or higher from the 1st through the 6th with an even 90° maximum on three consecutive days. Even at the International Airport, close to the cool waters of the ocean, the mercury climbed to 88° on the 2nd & 3rd. After this unusually early heat term, the airport thermometers did not climb above 76° for the rest of the month, and remained in the 60s and 50s for the 21–30th, to dramatize the reversal in seasonal thermal processes.

The entire coastline north to San Francisco shared the early heat. The mercury hit 77°, 79°, and 80° at the downtown Weather Bureau location in the Golden Gate City on the 2nd, 3rd, and 4th, setting new date records on the latter two days.

It was hot inland, too: Sacramento's 86° on the 4th was the hottest for so-early-in-the-season in record books dating for 83 years. Back in the desert, Yuma reached 100° on the 5th, 101° on the 9th, and 100° again on the 10th—all breaking or equaling long-standing marks.

After the 5th the ridge producing such strong



anticyclonic conditions over the Southwest, with its clear skies and warm subsiding air, lost its identity. Westerly flow of cool Pacific air plus frontal activity took command with typical maritime trough conditions featuring chilly temperatures and showery periods.

While surveying April's weather in the West, mention should be made of a most unusual rainfall which visited central and southern California on the 26–27th. At Los Angeles, where the season to date had been very dry, no measurable precipitation had fallen since March 28th; and fears were expressed, in view of the deficient rainfall of the previous year, of a severe water shortage in the rainless summer months to come. But much to the joy of the Angelenos, a rather peculiar circulation featuring convergence aloft produced an even 2.00″ of rain at the L.A. Airport in a 26-hour period on the 26–27th.

Lesser, but still substantial amounts fell to the north and south: San Francisco 1.45″ and San Diego 0.38″. The 24-hour catch at Los Angeles of 1.88″ comprised the most intense downpour ever experienced at this period in April. Even though the seasonal total would fall about 3.00″ below the normal amount of 12.10″, this late-season present was as unexpected as it was welcome. Readers of Weatherwatch may recall that at the beginning of the current rainy season a very intense storm for such an early date visited California on 17–19 September 1959, a full six weeks before the usual occurrence of the first heavy storm.

BIG EASTER STORM—The most widespread weather event of the month struck over the Easter weekend to spoil the traditional spring holiday for much of the country. A frontal disturbance moved inland on the Northwest Coast on Wednesday, the 13th; and 48 hours later at noon of Good Friday the center of the depression stood in Manitoba with an eastward-bulging front through Lake Superior and Wisconsin and then southwestward to a secondary wave on the front near Kansas City. The main center displayed great energy, deepened, and raced to Labrador by early Easter Sunday morning. The trailing front, however, seemed anchored by the developing wave in the Midwest, which in the same 36 hours moved eastward only to the Chicago area. The front now spread all the way from Labrador to Texas. Cold air poured down the western flank of the system with snow, cold rain, and thunderstorms over a large area of the Upper Lakes and Upper Mississippi Valley on the night preceding and throughout Easter Day.

Chicago was right in the center of the converging air masses. Close to the time of frontal passage on Saturday night a violent thunderstorm hit the area. Wind gusts up to 72 mph struck O'Hare Airport northwest of the city, and up to 55 mph at the Duneland Observatory southeast of the city (operated by AMS member Robert A. Ward). Heavy showers drenched the city. The temperature tumbled from 57° to 35°. On Easter Day the rain showers turned to snow showers by evening as the mercury hovered at freezing.

Thermometers dropped below freezing well into Iowa and Kansas at Easter sunrise when many were attending outdoors religious services. Up to 3 inches of snow fell across southern Wisconsin to hamper traffic on Sunday.

Though most Eastern cities lay in the warm sector on Easter and enjoyed above normal temperatures and a pleasant day, the entire frontal system accelerated its eastward progress on Sunday night to cause a rainy Easter Monday morning along the Atlantic Coast.

LATE EASTERN HEAT WAVE—The mercury reached 95° at the National Airport, Washington, D. C., on the 23rd for the highest ever recorded so-early-in-the-season. Only once before since records commenced in 1871 had the temperature soared to a 95° mark in April—on 27 April 1915. From the 23rd to 26th the thermometer averaged 20 or more degrees above normal with daily tops of 95°, 94°, 93°, and 91°.

The heat wave situation was created by an early appearance of that usual summer visitor, the Bermuda High. A "cold" front had cleared the Atlantic Coast on the 22nd, but was followed by warm Pacific air. An immediate build-up of high pressure over the Carolinas then pumped warm tropical air up the coastal plain into Virginia and northward to New Jersey. At the same time a "back-door cold front" pushed southwestward over New England. The conflicting air masses met in New Jersey where the front fluctuated back and forth for a four-day period, separating a hot south and west Jersey from a cold east and north Jersey. Commuters passing through the front moved from summer to early spring on their way to and from work each day. The following maximum temperature tabulation tells the story:

	Boston	New York City	Philadelphia	Wash., D. C.
23rd	45°	70°	91°	95°
24th	50°	62°	86°	94°
25th	57°	86°	92°	93°
26th	65°	63°	86°	91°
27th	54°	62°	69°	72°

The capital of Virginia had seven days with a maximum of 80° or higher—the four-day period with 90° or better, from the 23rd to 26th, had been equaled only once before in April in Richmond's 60 years of record. The maximum of 96° had been reached in only one previous April (1925). Nearer the coast Norfolk broke all April records back to 1871 with a searing 97° on the 26th—at the same time Cape Hatteras directly to the south, in the same circulation but with a trajectory over cool water, had only 75°. It is worth noting that all the mid-90° readings occurred in the coastal plain of Virginia and Maryland. Farther south it was hot, in the low 90s, but not as extreme as in the Middle Atlantic States where cloudless skies heated up the land and the lower layer of air to record proportions.

CANADIAN HIGHLIGHTS

April 1960 was a pleasant month throughout most of Canada with slightly warmer, drier, and sunnier weather than normal. Temperatures in southern Canada averaged normal to slightly above normal except in Newfoundland and southern Manitoba. The greatest temperature excesses were in northern Alberta where it was more than 6 degrees above normal for April. On the other hand, the northeastern Arctic experienced cold that was more than 6 degrees below normal.

Probably the most significant departure from normal weather in April occurred in the Maritime Provinces where the weather pattern showed a decided change from that of earlier months. Instead

of being affected by a succession of storms resulting in high winds and heavy snowfalls, conditions in these Provinces were remarkably stable, and in Nova Scotia all-time sunshine records were established for the month of April. Monthly totals of bright sunshine were in excess of 200 hours at most stations, breaking records that extend back 40 to 50 years in some instances. These stable weather situations, lasting several days at a time, were caused by pronounced blocking action over the north Atlantic Ocean and resulted in dry conditions on the east coast. Most of the month's precipitation occurred early, and the latter half of the month was sufficiently dry that the fire hazard situation became critical in Nova Scotia at month-end with numerous fires burning over large areas. In Newfoundland, St. John's Torbay Airport had only 1.14″ of precipitation, less than 25% of normal, and the lightest April precipitation since that station opened in 1942.

Throughout Canada the highest temperatures in April were reported from southwestern Ontario where both Sarnia and a suburban Hamilton station reported a maximum of 86°. In the Northwest Territories, Eureka, with a −45°, once again had the lowest temperature in the nation. For the month as a whole, several stations in southwestern British Columbia averaged 51°, while 50° at Windsor, Ontario, was the warmest in eastern Canada. For the other extreme, the average temperature for the month at Eureka was −22°.

Besides the Atlantic Provinces, the Northwest and Yukon Territories, along with northern British Columbia and Alberta, were quite dry. Both Resolution Island in Hudson Strait and Whitehorse, Yukon, reported only a "trace" of precipitation during the month. Heavy rains in northern Ontario, although not record breaking, contributed to the floods which were reported early in May, but the heaviest precipitation for the month was reported from Herbert Inlet on the west coast of Vancouver Island where 22.83″ were recorded.

A late season snowfall in the southern Prairie Provinces over the period 23–26 April left from 6 to 20 inches of snow in Alberta south of Calgary, and 5 to 10 inches in southern Manitoba. It was in Labrador, however, where there was an abundance of snowfall, as Cape Harrison reported 52″ of new snow and most of that district had in excess of 2 ft. At the end of the month snow cover in Canada was restricted to the area north and east of a line joining Aklavik to Lake Superior to Newfoundland. Deepest snow covers were in Labrador where several stations reported in excess of 4 ft. on 30 April.

As they were in March, atmospheric pressures were markedly higher than normal in the Canadian Arctic. Mean sea level pressures on the Arctic islands averaged more than 4 mb/.13″ above normal, while to the south both the Yukon and the Great Lakes areas averaged 4 mb/.13″ below normal. Frost was reported in all parts of the country except the extreme west coast of British Columbia. The north coast of British Columbia experienced seventeen days with gales, and a new wind record was established at Cape St. James where the maximum observed hourly speed was 85 mph. At Moncton, N. B., a station pressure of 968.5 mb/28.60″ April 5th was the lowest station pressure recorded in April for at least the past 21 years.

ALASKAN NOTES

Anchorage. The month of April had 25 cloudy days, exceeded only once before. Normal is 15. Temperature and precipitation were slightly below normal. The max. of 58° on the 30th was a date record. Monthly max. 58°, min. 11°.

Juneau. Snowfall of 1.3″ only one-third normal. Fair weather during latter part of month. Monthly max. 64°, min. 26°.

Nome. April had the lowest average temperature (9.5°) since April 1927. Departure from normal was −11.5°. Monthly max. 46°, min. −14°. Precipitation only 0.17″.

Barrow. Much below normal until the 24th when mercury soared to 29°. Coldest −30° on 4th. Min. below zero on all but 6 days. Snowfall 4.9″—snow cover steady at 13–15″ all month.

Cold Bay. The average temperature of 25.8° was the coldest recorded for any April since 1941 when observations began. Monthly max. 42°, min. 11°. No snow cover at end of month.

Fairbanks. The max. temp. of 74° on the 30th established a new record high for April. The month was generally cool and windy. Min. temp. −12°. Snow cover down to 1″ at end of month.

HAWAIIAN NOTES

Lihue, Kauai. Warm, dry and somewhat windy sums up the character of the weather this month. Average of 73.4° is highest since station established in 1950. Max. 83°, min. 62°. Precipitation 1.16″, or 1.87″ below normal.

Hilo, Hawaii. Average temperature of 72.0° was slightly above normal, as was precipitation of 15.04″. Heaviest rain in 24 hours was 3.08″ on 13–14th. Barometer ranged from 29.97″ to 30.18″.

Honolulu, Oahu. Normal trade wind weather prevailed throughout most of the month. With only .01″ rainfall it was driest April since 1947. The driest month ever was June 1959 with only a trace. Max. temp. 85°, min. 64°—average 74.9°.

PUERTO RICO NOTES

San Juan. Both temperature and precipitation above normal. Average temperature 78.4° with max. of 92° and min. of 65°. Measurable rainfall on 23 days for total of 5.76″. Heaviest in 24 hours was 1.13″.

March (*Continued from page 121*)

invading through Oregon and Washington, had reached extreme western Montana, and by the 9th a break-through followed to the edge of the western Plains. There the advance was checked, the front stabilized, and eventually pushed back a bit by a turn of air flow over the Plains to the northwest which brought Arctic reinforcements to the scene.

For the western half of the country the most spectacular pressure development of the month came with the arrival on the 14th of a deep low center on the shores of British Columbia, and the accompanying push of a great bulge of warm air inland over southwestern Canada and northwestern United States, bringing springlike conditions to the erstwhile realm of winter. As the new pressure impulse crossed the Rockies, a deep polar trough developed from the Arctic southward to Texas with the rapid

build-up of a balancing ridge to the west. Streamlines over the Plains reverted to a north-south air flow, and once again vast quantities of Arctic air surged southward, keeping well east of the Rockies, to prolong the already unprecedented cold spell in the Midwest, Upper South, and Northeast.

Ridge conditions continued to dominate all the area west of the Rockies. Under clear skies and a westerly air flow, temperatures soared. The week of 15–21 March averaged nine degrees above normal in southern California and also in western Montana with large plus departures in surrounding areas. During the following week the upper-air ridge held firm and a Plateau high at the surface gradually expanded its influence eastward with increasing warmth each day. The final break-through came in a spectacular manner on the 25–26th when warm air surged triumphantly across the Plains as was signalized by the quick temperature response over North Dakota, long under the control of the Arctic forces. On the morning of the 24th readings as low as −20° were registered there, while less than 60 hours later the mercury had soared to +75°—a change of 95 degrees! By the 28th the surge reached all the way to the Atlantic Coast: New York City 71° and Philadelphia 80°.

The explanation for the record continuance of March cold in the Midwest, East, and South can readily be found in the presence of well-marked troughs of low pressure somewhere east of the Rockies on every daily weather map. The movement of these upper-air troughs during the first 25 days of March proved extremely slow since westerly flow, which would have pushed them rapidly eastward, sank to very low seasonal levels.

With a northerly flow prevailing in the rear of each trough, cold air swept constantly into the entire area east of the Rockies to include Texas and the Gulf Coast. The most lagard of the troughs came with the pressure developments mentioned above on the 14–15th; this polar trough required eight days to pass from the Rockies to the Atlantic Coast, all-the-while stimulating cyclonic activity which, in turn, brought more cold air southward. The lethargic movement of this trough gave forecasters considerable trouble since the warm air, poised in the far West, threatened to break eastward at any moment. But the trough controlled the situation and made spring-lovers wait a full ten days for their first taste of balmy weather.

For the month as a whole, the mean trough line of low pressure extended in a southwesterly curve from Newfoundland, coming inshore between Norfolk and Hatteras, and then crossing the Southeastern States to reach the Gulf of Mexico in west Florida. The trough line marked the scene of maximum cyclonic action. During the first twenty days of March no less than five distinct depressions moved across the Southern States toward the Atlantic Ocean, and then raced northeastward following the Gulf Stream just offshore. Another low plunged southward in the trough area from Canada and then recurved eastward across Kentucky and Virginia to join the cyclonic parade. Cold air from the still-frigid interior of Canada followed in the wake of each disturbance to reinforce the supply of chilly air masses. As late as the 25–26th the mercury sank below zero in the Upper Lakes, northern New York, and New England. Date records for minimum readings were set over much of the Midwest and Northeast. At Sault Ste. Marie, Michigan, the low of −7° registered on the 25th, four days after the commencement of spring, was the lowest reached during the entire winter.

These depressions brought the greatest March snowfalls of record to coastal Carolina, increased seasonal totals in the southern Appalachians to all-time amounts, treated the cities of the Middle Atlantic plains to the season's heaviest snowfall, and then staggered southeastern New England with its greatest single snowstorm in Weather Bureau history. Farther west on Lake Ontario, Rochester added enough new snowfalls to far exceed its previous record for a seasonal total (record dates back to 1885). In the Midwest from southern Kansas to Lake Michigan continual snows piled up to record depths at mid-month. The high water content of the frozen mass held the threat of floods which was fully realized when the warm surge on the 27–28th sent the locked-up water surging into the streams of the lower Missouri and middle Mississippi Valleys.

MARCH NOTES

Miami, Fla. Temperature averaged 3.7° below normal. Max. 86°, min. 44°. Scattered frost in Dade County on 23rd. Violent squall on 31st with gusts to 53 mph; roaring sound reported; also hail. Precipitation only 0.67″, or 1.62″ below normal.

Tampa, Fla. Second wettest March on record. 9.35″ fell in a four-day period on 15–18th. Some reports in Pasco County up to 22.00″. Rains produced worst flooding since 1933. Damage $6 million.

Charleston, S. C. March was cold, windy, and unpleasant. Record number of days below 32° set at 8 days or double the previous figure. The lowest temperature at the airport (21°) was the lowest ever recorded for March and the lowest so-late-in-the-season. New record amount of snow and sleet for March fell on 11th with 1.0″.

Cape Hatteras, N. C. The average temperature was 10.2 degrees below normal, making March 1960 the coldest since the commencement of records in 1875. Snowfall of 8.5″ is the greatest snowfall on record for March.

Roanoke, Va. March was very cold with the temperature averaging 5.2 degrees below normal. The 30.3″ of snow broke all records for monthly snowfall back to 1901. Also records for the greatest depth (17″), and the greatest in 24 hours (17.4″). Rapid melting of snow caused small stream flooding on last 3 days of month.

New York City. This was the coldest March since 1916 (7.2 degrees below normal). The first 15 days were the coldest such period and thus set a record for the month with the most consecutive days with minimum daily temperature 25 degrees or lower. Since the daily minima from the 6th thru 13th were 20 degrees or lower, the record of 8 such days set in 1885 was equaled. On the 3rd 13.6″ of snow fell to set a date record—storm total 3–4th was 14.2″.

Providence, R. I. This was the 2nd coldest March on record, and the first it has been colder than the preceding February. The heaviest snowfall for any single storm was experienced on the 3rd–5th (17.7″) with gale force winds causing considerable drifting. Total March snowfall of 21.6″ exceeded only once before, March 1956 with 31.6″.

Nantucket, Mass. Second coldest March in 74 years and coldest in 45 years. Heavy snowstorm, high winds and tides on 3–5th, considerable waterfront damage. Total snowfall 3–5th was 31.3″, but due to a period of rain the greatest depth measured

was 19″. Monthly snowfall of 40.2″ established new record for any month—previous record 39.5″ in January 1904. Max. snow in 24 hours of 16.1″ also exceeded previous record of 11.9″ set in 1916.

Milton, Mass. The storm total of 30.3″ on the 3–5th at Blue Hill Observatory set a new record for its 76-year history. The 27.2″ measured on the 3–4th was also a 24-hour record. Melted precipitation in storm totaled 3.15″. Greatest snow depth was 30″ on 5th. In the April *Weatherwise* account of this storm, the Milton figures were erroneously attributed to Uxbridge, Mass.

Rochester, N. Y. The season total snowfall to date is 161″, or 19.5″ more than any other season of record back to 1885. This is the third coldest March in 130 years of Rochester weather records with 22.4° or 10.6 degrees below normal. Coldest was 21° in 1885, and 2nd coldest 22° in 1872.

Milwaukee, Wis. March 1960 was the coldest March since records began in 1871. Minimum of −9° was the lowest on record for any March. Record low temperatures were also established on 5 days. Other records broken were the number of days with maximum temperature of 32° or lower which was 24, as compared with the previous largest total of 19 in 1877. The snowcover of 24″ on 3–4th was close to the record 26″ in Jan. 1918. Total snowfall for season so far of 91.3″ is third heaviest for any full winter.

Peoria, Ill. The monthly average of 22.6° was the coldest March in 104 years of record. The previous record low of 28.4° was set in 1912. Total monthly snowfall of 16.9″ was second only to March of 1926.

St. Louis, Mo. This was the coldest March on record (30.3°); the previous record was 33.7° in 1906. The 5th with −5° was the coldest so-late-in-the-season, the coldest this winter, and the first time a March day was the coldest for the winter season—records date back to 1871. Also March was the coldest winter month this season, the first time in history. The snowfall of 22.3″ has been exceeded only by March 1912. Snow covered the ground for 29 consecutive days ending on the 23rd. The first sign of green on lawns occurred after a thunderstorm on the 29th.

Omaha, Neb. This March was the coldest on record with 23.1° or 15.1 degrees below normal. The previous coldest March came in 1899 with 26.8°. The snow depth of 27″ on the 16th was the greatest depth of snow on the ground since records commenced; previous record was 22″ in 1948. March 28th marked the last day of 75 consecutive days with 1″ or more on the ground which exceeds former record of 66 days in 1939–40. Total snowfall to date of 56.7″ is 3rd greatest of record.

Topeka, Kan. By far the coldest March of record—average 27.8° or 14.8 degrees below normal. Most snow since 1912. First time since 1948 with a March subzero reading. Repeated snows from 20 Feb. to 15 March totaled 36″, more than in any previous similar period. Depth of 19″ on 15th the greatest of record. Construction work greatly curtailed or halted. Feeding and care of livestock particularly difficult account muddy or snow-clogged roads and feedlots.

Dallas, Tex. This was the coldest March in 45 years, and the second coldest of record—temperature averaged 8 degrees below normal. The month was rather dry, with precipitation being 34% of normal. Strong dust-laden westerly winds reduced visibility to 3 miles on 15th.

Helena, Mont. The month was neatly divided into two segments of about the same length: the first very cold, the last very warm for the season. By mid-month temperatures had averaged 10 degrees below normal. These two segments of opposite character are obscured by the +0.4 degree average temperature for the month as a whole.

Yakima, Wash. The low temperature of −1° on the 4th was a new record for the day and also the coldest temperature ever recorded after February 15th since records began in 1909. New daily high records were set on the 24th & 25th. Warm temperatures after mid-month brought fruit from 8 days later to 5 days earlier than usual by month-end.

Seattle, Wash. An unusually heavy snowfall for late season on 3rd. Snow depth downtown reached 4″ by noon with more in suburbs. Some remained on higher ground until morning of 5th. New date maxima on 24–25th—highest 67°.

Los Angeles, Calif. Average temperature above (3.1°), and precipitation well below (−2.05″). Only two rain periods: 0.09″ on 1st and 0.22″ on 27–28th. Max. temp. 89°, min. 46°.

Prescott, Ariz. March was unusually warm and pleasant. 78° on the 21st equaled the record high of 1956 and was the highest of record for so-early-in-spring. The 4 60-degree days were the least of record for any March.

Yuma, Ariz. March was warm and dry following the cool, wet winter. The average monthly temperature of 69.8° was the highest since 1934. The max. on 20th & 21st set new date records—both 96°. Rainfall totaled only 0.03″.

CANADIAN HIGHLIGHTS

The most noteworthy Canadian weather in March 1960 occurred in the Atlantic Provinces where the stormy pattern that had been in evidence earlier in the winter continued through the month. The worst storms occurred in the period from March 15 to March 19 when heavy snow and strong winds blocked roads bringing travel and transportation to a halt in many areas.

Record-breaking March snowfalls were reported from several locations such as St. John's, Nfld. 73″, Copper Lake, N.S. 73″, Gander, Nfld. 65″, and Halifax, N.S. 55″. However, unless the month of April brings heavy snowfall to the Atlantic Provinces, totals for the season 1959–60 are far short of the all-time records except at Halifax where the total this year to the end of March is 135″ against an all-time snowfall season record of 143″. In Newfoundland at Gander Airport, 163″ have fallen this year to date, compared to an all-time record of 236″ for a winter season.

With the exception of the Atlantic Provinces and small areas in British Columbia, all Canada had below normal temperatures in March 1960. In British Columbia and Alberta the first two weeks were cold, but much warmer conditions in the next two weeks brought the average temperature up to 1 to 4 degrees below normal for the month as a whole. In Ontario during the first two weeks a ridge of high pressure extending down over the area associated with a continuing flow of cold air from the north brought exceptionally cold weather to the Great Lakes region.

Temperatures were continually below freezing and did not warm up appreciably in the last two weeks of the month, which was generally cloudy and cold. At Toronto, the month was the coldest March since

1912 and also the coldest month of the 1959–60 winter. This is only the third time in 120 years that March has been the coldest month of a winter season. Southern Ontario averaged from 7 to 11 degrees below normal, while other relatively cold spots were the Hudson Strait area where Indian House Lake and Fort Chimo were 12 degrees below normal and the upper Mackenzie River basin in the Northwest Territories where the temperatures were 8 to 10 degrees below normal.

Temperature extremes were rather severe throughout the whole country, as some areas in western Canada as far south as the International border had extreme minimums lower than 30 degrees below zero. Heating degree day totals were high and no part of the country escaped frost during the month. The coldest temperature recorded during the month was 60 degrees below zero at Eureka, and the warmest was 75 degrees at Lytton, B. C.

With relatively high pressure over the Great Lakes region, this was the sunniest March in southern Ontario since 1918. Abundant precipitation, especially snowfall, led to a record number of precipitation days in Nova Scotia, where several stations reported measurable precipitation on 21 or 22 days. Also as a result of this storminess, Gander, Nfld., had an average wind speed of 20 mph—the windiest March on record.

A freezing precipitation storm in Quebec City on 31 March, did more damage than any other such storm in the past 15 years. Weather stations in southern Manitoba reported a thunderstorm on 28 March. At Winnipeg where the temperature was 34 at the time of the storm, this was only the fifth time since 1895 that thunderstorms have been reported in March.

A temperature of 67° at Vancouver on March 25th is a record March high temperature for Vancouver Airport while many stations in interior B. C. reported higher maximums than any in the past decade. For the month as a whole, the Vancouver-Victoria area of British Columbia with a mean temperature of 43° was the warmest in western Canada, while Halifax with a mean temperature of 31° was the warmest city in eastern Canada. Eureka, N.W.T., on the other hand had a mean temperature of −39°, the coldest location in the country.

Heaviest precipitation in March 1960 was reported from Ethelda Bay, B. C., with 24.19″ and at the end of the month several Newfoundland stations reported in excess of 5 ft. of snow on the ground.

ALASKAN NOTES

Nome. Precipitation equaled the least ever recorded for any month and was the lowest since May 1928 —only a trace. Max. temp. 37°, min. −22°.

Anchorage. The month was colder than normal by 3.8°, but a preponderance of clear to partly cloudy skies and an abundance of sunshine, together with subnormal snowfall (5.1″), made March of 1960 a pleasant month in most respects. The depth of snow on the ground at month's end had fallen to 4″, a reduction of 11″ since 19 March. Max. temp. 41°, min. −4°.

Barrow. The fastest mile of 58 mph on 1st set a new record for March. Highest barometer 31.18″ on 9th. On the 18th max. temp. was −25°, min. −40°. March max. was 29° on 1st, min. −41° on 19th.

Fairbanks. The month was relatively cool (average 4.2°, or 4.8 degrees below normal), windy (7.8 mph average speed), and dry (only 0.20″ precipitation, or 0.38″ below normal). Max. temp. 43°, min. −29°. No zero days.

HAWAIIAN NOTES

Honolulu. A new March record high temperature of 89° was established at this station. During the first half of March trade winds were almost absent, and there were four frontal passages at Honolulu, an unusually high number. The first of these was very slow moving, remaining in the vicinity of Oahu over a week and was associated with the bulk of the month's rainfall. Humidities during this period were high. Beginning on the 17th, winds were predominately from the trade direction and only traces of rain were observed. Max. 89°, min. 59°. Rainfall 1.48″, or 0.82″ below normal.

Lihue, Kauai. The highest temperature of 85° exceeded by two degrees the highest for March on record. A rainy spell, which began the last couple of days of February, continued for the first week—total 9.72″. Nearly 90% of the month's rainfall fell in the first seven days, and just under 50% in 24 hours on the 2–3rd when 4.74 fell.

PUERTO RICAN NOTES

San Juan. Temperature averaged 2.3 degrees above normal. Max. 90° on 12th, min. 62° on 4th. Rainfall was close to normal with 2.40″ and well distributed throughout month. Max. in 24 hours was 0.72″. Pressure varied from 30.16″ to 29.86″.

ERRATA

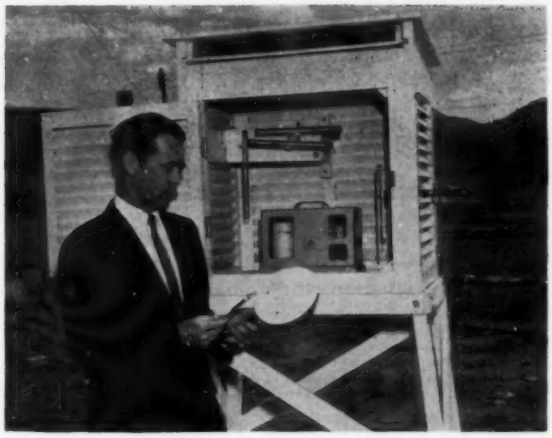
MARCH SNOWSTORM

In the April *Weatherwise* the total snowfall figure for Blue Hill Observatory of 30.3″ was by editorial error attributed to Uxbridge and so appeared in both text and on the map. The Blue Hill figure represents a new record for any storm in the 76-years of careful record there. Many stations in southeastern New England reported official totals from 20″ to 25″, confirming the earlier opinion that this, indeed, was the greatest snowstorm in modern history for the area. Boston's correct total figure, as measured at Logan International Airport, was 19.8″.

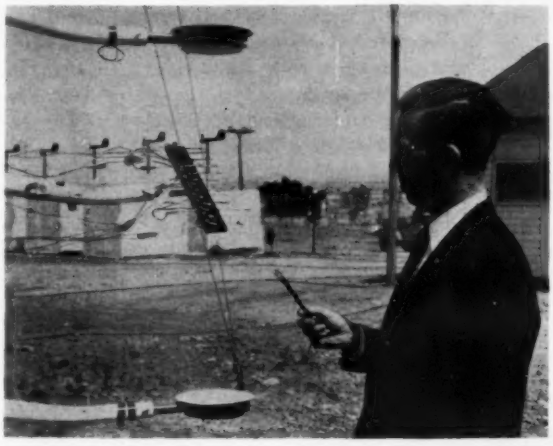
TYPHOONS

Readers of *Weatherwatch* who might like to follow typhoon activity each year may do so by consulting the May issue of *Mariners Weather Log*. "Typhoons of the Western North Pacific," prepared by the Joint Typhoon Warning Center, Guam, M. I., describes the salient data on 17 typhoons occurring from April to December 1959. *Mariners Weather Log* is a publication of the U. S. Weather Bureau and may be secured from the Supt. of Documents, Wash., D. C. at 20¢ per copy.

Toward More Accurate Temperatures



Glenn E. Daniels of the Meteorology Department, U. S. Army Electronics Proving Ground, Fort Huachuca, Arizona, is comparing a new thermocouple, which he designed to eliminate the effects of radiation, with older types of temperature measuring devices.



Mr. Daniels holds one of his latest type thermocouples. In center can be seen ten additional new-type thermocouples suspended from middle arm; above and below on individual arms are two traditional white radiation shields. In background are automatic weather stations on test.

Outdoor thermocouples transmit to indoor strip chart recorder. Mr. Daniels explains their operation to Lt. Col. A. E. Sutherland, USAFR. The Army Signal Corps has filed for a patent on the new thermocouple. All photos by Pfc Karl Traber, USAEPG.

PAN AMERICAN WORLD AIRWAYS, INC.

GUIDED MISSILES RANGE DIVISION

UNUSUAL OPPORTUNITIES FOR FOREIGN–BASED AND STATESIDE EMPLOYMENT

RAWINSONDE OPERATORS

Minimum qualifications: U. S. Citizen. Three to four years weather experience operating Rawinsonde equipment. Familiar with all phases of operation, working up and coding data obtained. Also required to take Surface Weather Observations.

Send resume of experience to:

EMPLOYMENT SUPERINTENDENT
PAN AMERICAN WORLD AIRWAYS
GUIDED MISSILES RANGE DIV.
PATRICK AFB, FLORIDA

Gettysburg (*Continued from page 105*)

starry heavens, the winds and clouds; he roamed the fields. The great outdoors was a laboratory for him. But he also knew the value of the test tube and the balance. He appreciated the importance of the controlled observation, which we call an experiment. In the "science room" on the southwest corner of the second floor of "Old Dorm," he not only made scientific demonstrations before his classes but he also performed original experiments. He was a pioneer spirit; he could see new problems and devise new solutions.

His most noteworthy original work was in Meteorology. In this field he was a pathfinder. He began making observations early in life and continued almost to the day of his death. The results were systematized in his "Lectures on Meteorology," which were announced first in 1841. Later he introduced Brocklesby's *Meteorology* as a text to be used in connection with his lectures. In 1846, he read a paper before the American Association for the Advancement of Science on "The Indian Summer." The theory that he advanced for explaining that phenomenon called forth much favorable comment at that time. He published no books and few articles. But the little that he did publish shows that he had the spirit and method of a true scientist. Those who knew him account for his silence as due to excessive modesty."

Research and Manpower in Meteorology

The Committee on Atmospheric Sciences of the National Academy of Sciences has issued a report entitled: The Status of Research and Manpower in Meteorology. This is publication No. 754 of the National Academy. The report represents a summary of the status, at the beginning of 1960, of training and research in the meteorological sciences in American universities and also considers Federal support of meteorological research. The report concludes that "there is a very vital need for greater attention to the educational program in the atmospheric sciences at our universities. The ever increasing demands on research, manpower, and capabilities must be met within a reasonable period of time so that progressive advances and continuing inquiry will not be delayed."

Local Storms (*Continued from page 100*)

tornadoes and damaging winds in the Oklahoma City vicinity later that evening.

Since the objective of the project is an investigation of severe local storms, the code name, "Rough Riders," is used for FAA and Weather Bureau communications with the aircraft.

The Severe Local Storms Research Network of surface stations in Kansas, Oklahoma, and Texas is also being used to supplement conventional surface observations. Over 200 stations of this network record pressure on expanded 12-hour barographs; and temperature, humidity, and rainfall are also recorded at many of the stations. Plans for 1961 and 1962 provide for a dense internal network of similar stations southwest of Oklahoma City as a supplement to the present network.

During the severe local storm season regular rawinsonde stations are augmented by mobile upper-air stations of the Air Weather Service. Five of these trucks are located in Texas, Oklahoma, and Arkansas. Additional upper-air observations are provided by scheduling serial observations at one-to-two hour intervals from selected regular and mobile rawinsonde stations. The first set of serial observations was made from five stations on 4 May 1960. Observations were made at 90 minute intervals for the period 1200 to 1800C and covered the incipient and early activity stage of the many tornadoes and hailstorms that occurred in Oklahoma and Texas that day.

Rockets fired from the Fort Sill Military Reservation, Oklahoma, will be used for high-level photography of squall lines. The New Mexico State University, under contract with ONR, will conduct the firings.

The cooperation of several agencies in the conduct of the project is an indication of their serious interest in severe local storms. Through these agencies immediate and long-term needs that are both operational and research in nature are being met. The detailed measurements of many parameters in time and space by the "Rough Riders" of NSLSRP will provide a better understanding of severe local storms.

The new

WHITE WINDMASTER

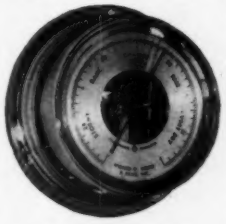
WIND-SPEED INDICATOR $59.95

WIND-DIRECTION INDICATOR $69.95

Provides wind-speed and wind-direction information at a new high level of precision and sensitivity . . . handsome brass or chrome 4" dials (5½" overall). . . . Three spinning cups generate electricity and record wind speeds on 0 to 50 and 0 to 120 m.p.h. dial . . . accurate within 2 per cent . . . no current needed.

New "split-vane" construction and balanced assembly record wind-direction changes more quickly . . . lifelong maintenance-free operation . . . 110 V.A.C. or 6 V.D.C. Complete wind information and satisfaction.

Circular available



New WHITE BAROMETER

has an exceptionally fine movement, compensated for temperature changes. Its brass or chrome case and dial match those of the White wind instruments.

$52.50

WILFRID O. WHITE & SONS, INC.
178 ATLANTIC AVE. BOSTON 10, MASS.

Send for Bollinger's Atlas of

PLANETARY SOLAR CLIMATE

with Sun-tide Indices of
Solar Radiation and Global Insolation

and make scientific forecasts

of

SEASONAL WEATHER AND CLIMATE

in Your Locality

7 Planet (8 day interval) Sun-Tide Indices
1900-59 - - - $6.00

7 Planet (5 day interval) Suntide Indices
Year 1960 - - - $1.00

Published by
BATTENBURG PRESS
P. O. Box 2026
Norman, Oklahoma

Ice-Fall (*Continued from page 114*)

metorologists. It is amusing to note that it seems to be the weatherwise in Franklin's own Philadelphia who may be in by far the best position to unravel this peculiar puzzle of the ice-fall problem.

After completion of the above, the writer inquired of the Federal Airways Agency concerning FAA studies of the ice-fall problem. An official of the FAA stated that the Agency is well aware of the problem and has conducted investigations (centering, apparently, around the wastewater hypothesis). A Civil Air Regulation has been passed, affecting all transports manufactured subsequent to October, 1959, requiring that, on transports discharging any liquids, drain location and design shall be such as to preclude ice accumulations. A review of all available reports on ice-falls is planned by the FAA for the near future.

Another item of information also received concerns a very unusual ice-fall on 4 June 1953 in Long Beach, California. Newspaper clippings from the 5 June 1953 Long Beach *Press-Telegram*, loaned to me by the NICAP office, state that about 50 chunks of ice, some estimated to weigh 150 pounds each, fell over a two-block area. Although no persons were hit, a number of cars were damaged. An Air Force spokesman suggested that if dew point and temperature were close enough together a small piece of ice might grow, like a hailstone, as it fell, an explanation quite unacceptable on meteorological grounds. On 9 June, CAA inspectors made a public statement that "several large Air Force craft were flying sufficiently high over the area to have caused the icing conditions and subsequent 'bombing'." To check the plausibility of the latter, I examined weather data for that date and found that throughout the entire state of California there were only three out of about 500 cooperative U. S. Weather Bureau stations that reported even a "trace" of precipitation, plus one station (Susanville, far north of Long Beach) with 0.01 inch. That any accumulations of ice such as fell on Long Beach could have resulted from aircraft icing under such weather conditions seems out of the question. Finally, the wastewater hypothesis seems unreasonable as an explanation for such impressive total amounts of ice, so no acceptable explanation is at hand for this ice-fall.

Science in Space

A series of reports in chapter form prepared by the Space Science Board has been issued recently. The Space Science Board of the National Academy of Sciences was established in 1958. Two members of the AMS are Board members.

The purpose of the reports is (1) to review areas and opportunities for research studies using space vehicle and (2) to suggest what now appear to be major areas of emphasis for the national space effort.

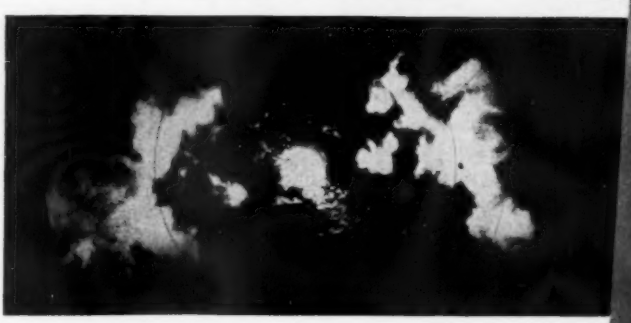
The reports have appeared in chapter form, varying from 12 to 36 pages each. The contents of the chapters follow: (1) A General Review, (2) The Nature of Gravitation, (3) The Earth, (4) The Moon, (5) The Planets, (6) The Sun, (7) Physics of Fields and Energetic Particles in Space, (8) Galactic Astronomy, and (9) The Biological Sciences and Space Research.

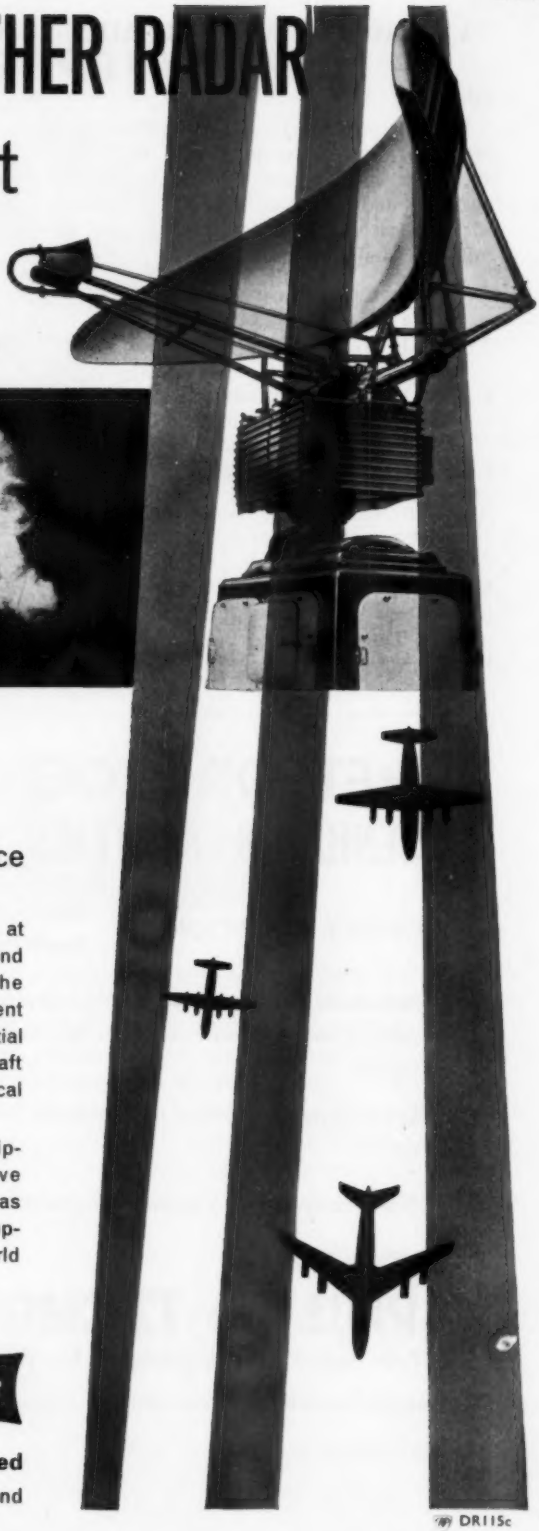
Each chapter may be obtained for $1.00 each from the Printing and Publication Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Wash. 25, D. C.

D9450

DECCA WEATHER RADAR

for Airport Weather Services





Over 60

Decca Weather Radars are in service

Decca Weather Radar is being installed at major civil airports to provide immediate and continuous information concerning the position, extent, development and movement of precipitation in terminal areas—essential information if the jet and turbo-prop aircraft of today are to maintain safe and economical flight paths at all times.

Sound, reliable and advanced radar equipment, allied to a most comprehensive operational and technical training service, has made Decca Radar Limited the leading suppliers of meteorological radar in the world today.

DECCA RADAR

Decca Radar Limited
London · England

DR115c

ANTARCTIC WEATHERMEN NEEDED

Editor:

We are now recruiting replacement personnel for duty in the Antarctic. Any assistance you can give us relative to locating available and interested qualified candidates will be greatly appreciated. Tentatively, the following staff is proposed:

1	GS-13	$9890	Meterologist
4	GS-12	$8330	Meteorologists
2	GS-11	$7270	Meteorologists or $7510 Physicists
4	GS-11	$7030	Electronic Technicians
1	GS-11	$7030	Meteorological Technician (Supervisory)
9	GS-9	$5985	Meteorological Technicians

Appointments will be for a contract period of 18 to 24 months including a rather extended period of training and indoctrination in the United States. Incumbents will serve approximately one year actually in the Antarctic. They will depart from the United States in October or November of this year, and will return in December 1961 or January 1962.

In addition to the regular per annum salaries indicated above, an allowance approximating $2800 per year will be paid for the time spent in Antarctica in lieu of overtime and night differential. Also quarters, subsistence, and polar clothing will be furnished free of charge.

Additional information and application forms may be obtained by writing, Chief, Personnel Management Division, U. S. Weather Bureau, Washington 25, D. C.

Again, we want to thank you for your assistance in publicizing our need for personnel for Antarctic assignments.

J. J. Davis, Chief
Personnel Management Division
U. S. Weather Bureau
Washington 25, D. C.

Ed. Note: This and similar openings were listed in the May issue of the AMS Employment Bulletin. This service is open to all AMS members.

METEOROLOGICAL
SENIOR & SYSTEMS ENGINEERS

CHOICE LOCATIONS: **Northeast U.S.**
Southeast U.S.

Individuals must be capable of developing and establishing engineering concepts, standards, and criteria for installation of meteorological equipment and systems.

Excellent starting salary and company paid benefits including relocation assistance.

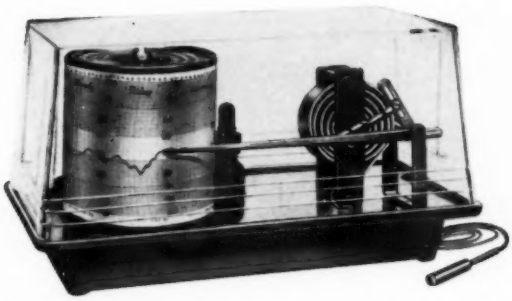
Direct comprehensive detailed resume to—

MR. D. E. DIMMIG

PHILCO TECHREP DIVISION

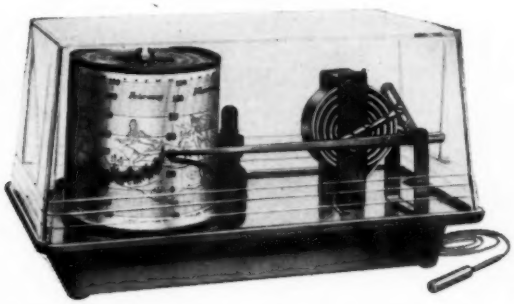
P.O. Box 4730, Philadelphia 34, Pa.

Low Cost Thermographs



No. 157. Remote-reading Recording Thermometer. An eight-foot, armored, liquid-filled tubing connects an outdoor temperature-sensitive bulb to an indoor recorder. A bourdon spring actuates the movement of the pen arm. An electrically-driven chart drum revolves once in seven days. Charts are graduated in one-hour segments. Range is −40° to +120° F. Requires 115 v. 60 cy. house current for electric chart drive. Complete with 13 charts, ink and instructions. Additional charts are $5.00 per 50.

$49.50



No. 158. Seasonal Recording Thermometer. A unique instrument which records maximum and minimum temperature for each day over a period of six months without chart change or other attention. An electrically-driven chart drum revolves once in six months. Pen arm is actuated by remote outdoor bulb at end of 8-foot armored, liquid-filled tubing. Pen moves vertically up and down chart during a 24-hour period, marking max. and min. readings for that period. Then a stepping action moves the chart forward once every 24 hours for recording the next day's max. and min. Charts have two-degree graduations with range −40° to +120° F. Charts have appropriate seasonal symbols each month. Requires no attention or chart-changing except once every six months. Operates on 115 v. 60 cy. A.C. current.

$59.50

SCIENCE ASSOCIATES, INC.

Instruments/Weather · Astronomy/Teaching Aids

P. O. Box 216 **194 Nassau Street, Princeton, N. J.**